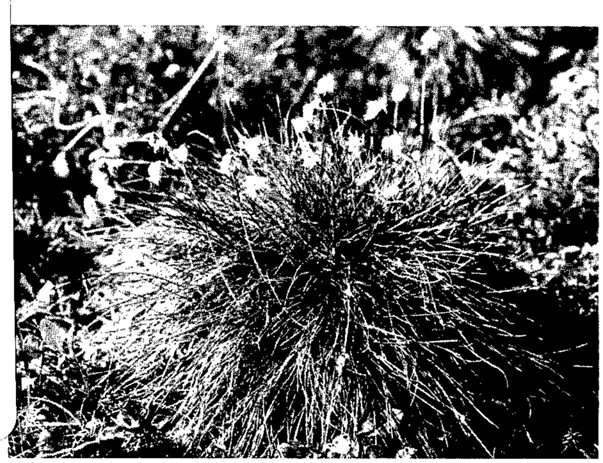
BIOLOGICAL REPORT 89(7)
JUNE 1989

WETLAND SOILS AND VEGETATION, ARCTIC FOOTHILLS, ALASKA



19970320 120

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

Fish and Wildlife Service

U.S. Department of the Interior

DTIC QUALITY INSPECTED 1

Biological Report 89(7)
June 1989

WETLAND SOILS AND VEGETATION, ARCTIC FOOTHILLS, ALASKA

by

Marilyn D. Walker, Donald A. Walker, and Kaye R. Everett
Walker Geobotanical Surveys
956 Clover Cir.
Lafayette, CO 80026
303-665-3487

Contract Number
14-16-0009-85-001

Project Officer

Charles Segelquist
National Ecology Research Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Creekside One Building
Fort Collins, CO 80625-2899

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

DISCLAIMER

The opinions and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the U.S. Fish and Wildlife Service, nor does the mention of trade names constitute endorsement or recommendation for use by the Federal Government.

Suggested citation:
Walker, M.D., D.A. Walker, and K.R. Everett. 1989. Wetland soils and vegetation, Arctic Foothills, Alaska. U.S. Fish Wildl. Serv. Biol. Rep. 89(7). 89 pp.

PREFACE

The National Ecology Research Center of the U.S. Fish and Wildlife Service (FWS) is supporting a series of field research studies to document relationships between hydric soils and wetland vegetation in selected wetlands throughout the United States. This study is one of that series. It is a continuation of the FWS effort, begun by Wentworth and Johnson (1986), to develop a procedure using vegetation to designate wetlands based on the indicator status of wetland vegetation as described by the FWS "National List of Plant Species that Occur in Wetlands: Alaska (Region A)" (Reed 1988). This list classifies vascular plants into one of five categories according to their frequency of occurrence in wetlands. Concurrent with the development of the wetland plant list, the Soil Conservation Service (SCS) developed a National list of hydric soils (SCS 1985). Studies supported by the National Ecology Research Center quantitatively compare associations of plant species, designated according to their hydric nature using the Wentworth and Johnson (1986) procedure, with the hydric nature of soils according to their designation on the SCS hydric soils list. The studies are being conducted across moisture gradients at a variety of wetland sites throughout the U.S. Several studies have been modified to obtain concomitant information on groundwater hydrology.

These studies were conceived in 1984 and implemented in 1985 in response to internal planning efforts of the FWS. They parallel, to some extent, ongoing efforts by the SCS to delineate wetlands for Section 1221 of the Food Security Act of 1985 (the swampbuster provision). The SCS and FWS provided joint guidance and direction in the development of the Wentworth and Johnson (1986) procedure, and the SCS is currently testing a procedure that combines hydric soils and the Wentworth and Johnson procedure for practical wetland delineation. The efforts of both agencies are complementary and are being conducted in close cooperation.

The primary objectives of these studies are to: (1) assemble a quantitative data base of wetland plant community dominance and codominance for determining the relationship between wetland plants and hydric soils; (2) test various delineation algorithms based on the indicator status of plants against independent measures of hydric character, primarily hydric soils; and (3) test, in some instances, the correlation with groundwater hydrology. The results of these studies also can be used, with little or no supplementary hydrologic information, to compare wetland delineation methods of the Corps of Engineers (1987) and the Environmental Protection Agency (Sipple 1987).

The present study differs from previously published reports in this series to the extent that it is based on baseline vegetation and soils data collected for a larger ecosystem study, rather than new data collected specifically for the purpose of determining soil-vegetation relations in arctic wetlands. Thus, the study examines the general ecology of the study site and the sample plots as well as detailed relations among soils and vegetation.

Any questions or suggestions regarding these studies should be directed to: Charles Segelquist, 2627 Redwing Road, Creekside One Building, Fort Collins, CO 80526-2899; FTS 232-5384 or Commercial (303) 226-9384.

SUMMARY

Analyses of relationships between hydric soils and wetland plant species were made at a 22 km^2 site in the northern foothills of the Brooks Range, Alaska, as part of a cooperative effort between the FWS and SCS to develop methods for field identification of wetlands and hydric soils. The site is considered to be representative of broad regions of acidic tussock tundra in the foothills. A three-level, hierarchical, floristic classification of the site vegetation contains 9 groups, 16 subgroups, and 23 community types. Seven soil types (subgroups) were identified at the site: Pergelic Cryofibrists, Hemic Pergelic Sphagnofibrists, Pergelic Cryohemists, Histic Pergelic Cryaquepts, Pergelic Cryaquepts, Pergelic Cryorthents, and Pergelic Cryochrepts. All except the last two are considered hydric. Weighted and index averages were calculated for each of 84 samples by weighting each species according to its wetland indicator status in a published list of vascular wetland plants of the U.S. This resulted in a value between 1 and 5, with 1 indicating obligate wetland and 5 indicating upland. Analysis of variance among soil types using averages based on vascular species alone or in combination with cryptogamic species (mosses, liverworts, and lichens) led to a highly significant statistical distinction between hydric and non-hydric soils. Cryptogamic species, which have not been reviewed for wetland status, did not separate the soil types properly. Bryophytes produced indices that were too low, i.e., toward the wet end of the scale, and lichens produced indices that were too high. Thus, indices based on vascular species alone, which are easiest to identify in the field, appear adequate for separating hydric and non-hydric soils. Pergelic Cryaquept soils, which occur primarily on slopes, had a mean index value of 2.9, which is very near the suggested borderline of 3.0 for hydric soils. Although this soil type is technically hydric, because at least its lower mineral horizons will be saturated through most of the growing season, the upper organic horizons, where plants are rooted, may become very dry during the course of the growing season. For this reason, the application of hydric soil definitions designed primarily for temperate regions are questionable in arctic regions underlain by continuous permafrost.

As a further test of the use of published species lists, calculated sample index averages were used to calculate new species index averages. This resulted in a total of 28 species (25% of the total number) that differed from their published indicator status by at least 1.0 unit, suggesting that they may require further review. This method proved very useful for testing the list, and many rather severe misclassifications were noted that might have been missed otherwise. This method is also useful for species that are not included on published lists. Species averaging could become part of the standard methods for these studies.

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

Much of the data contained in this report were collected under Department of Energy contract no. DE-FG02-84ER60242 to the University of Colorado. Jennifer Caine, Michael Figgs, David Kallenbach, Nancy Lederer, Diane Lorenz, and Tom Van Dreser assisted with data collection, analysis, and report preparation. The manuscript was improved by the comments of Stephen J. Brady, Frank C. Golet, Porter B. Reed, Charles Segelquist, and Bill Slauson.

INTRODUCTION

This report is one of a series sponsored by the FWS to examine relationships between wetland plants and soils in a variety of habitats. It examines a first order watershed in the Arctic Foothills of the Brooks Range, northern Alaska, which is representative of similarly aged surfaces in the foothills region. Its major purpose is to determine if soils meeting the Soil Conservation Service (SCS) definition of "hydric" support wetland plant species as defined by Reed (1988). The FWS wetland classification system (Cowardin et al. 1979) defines wetlands as:

> ...Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purpose of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Although all 50 States contain some wetlands, more than half of Alaska has been mapped as wetland, and over two-thirds of the total wetlands in the U.S. today are in Alaska (Tiner 1984; Ford and Bedford 1987). Northern Alaska differs from the lower 48 States and southern Alaska with regard to its wetland status because of continuously frozen ground (permafrost) throughout the region, which affects all phases of the hydrologic cycle (Church 1974; Harlan 1974; Woo 1982). Permafrost is a "confining bed of low but finite permeability" (Williams and van Everdingen 1973), and therefore provides a sealed hydrologic barrier. The ground freezes in winter and begins to thaw from the surface downward following snow melt. This relatively shallow annually thawed surface, or active layer (10 to 200 cm in depth), is where all biological activity occurs. Only steep slopes and ridge tops in permafrost regions will not meet at least the second criterion of Cowardin et al. (1979), that the substrate is predominantly hydric. As the frozen ground thaws in spring, the water is held in the soil. Air and soil temperatures are both just above freezing at this time, and there is little evaporative loss.

Northern Alaska is currently in a period of intense development and rapid environmental change. The discovery of oil at Prudhoe Bay in 1968 has led to major developments on the coastal plain. Although development has been mostly limited to the coastal plain, the trans-Alaska pipeline traverses all the major physiographic regions on the North Slope, including about 150 km of foothills (Brown and Berg 1980). Future oilfields and transportation corridors will undoubtedly impact other foothill areas. There has been relatively little ecological work done in the foothills because of the remoteness of the region and the currently greater need for information in the Arctic Coastal Plain region. Because of the relative scarcity of published information on foothills soil and vegetation, much of this report is devoted to description of the hydrology and geobotanical characteristics of the site. Most of this information is summarized from investigations conducted as part of the Department of Energy's R4D (Response, Resistance to, Resilience to, and Recovery from Disturbance) research program.

SITE DESCRIPTION

The study was conducted within a 22-km² area that is the main research site for the Department of Energy's R4D program. The R4D study area, located at 68°37'N, 149°12'W, contains two first order watersheds and is situated in a shallow basin at the foot of the central Brooks Range (Figure 1). The area includes the headwaters of the informally named Imnavait Creek.

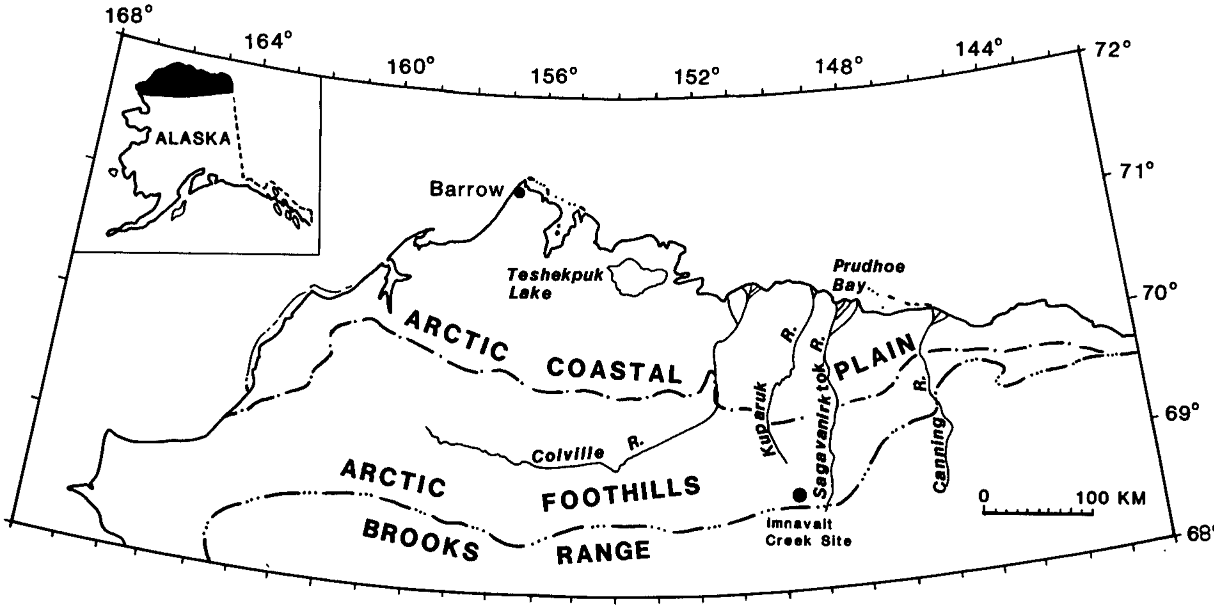


Figure 1. Physiographic provinces of northern Alaska (Wahrhaftig 1965) and location of the Imnavait Creek site.

REGIONAL SETTING

The Arctic Foothills Physiographic Province and the Imnavait Creek Site

Alaska's North Slope stretches from the crest of the Brooks Range north to the Arctic Ocean. It is characterized by continuous permafrost, lack of trees, snow cover for 7 to 9 months, winter ice cover on all water bodies (including the ocean), and suspension of river flow in winter (Walker 1973). Three physiographic provinces subdivide the region: the Brooks Range, the Arctic Foothills, and the Arctic Coastal Plain (Wahrhaftig 1965; Figure 1). These provinces, although they share the characteristics listed above, are distinct with respect to climate, vegetation, landscape age, and topography.

The Arctic Coastal Plain is flat and wet with abundant oriented thaw lakes (Black and Barksdale 1949) and covers about 61,000 km^2 (Walker 1973). The area was never glaciated, and its surficial deposits are primarily alluvial and marine (Rawlinson 1984). In contrast, the Arctic Foothills Physiographic Province is a broad expanse of glaciated valleys and hills about 95,000 km^2 in extent (Walker 1973) and "characterized by irregular buttes, knobs and mesas, east trending ridges, and intervening rolling tundra plains" (Arctic Environmental Information Data Center 1975). Lakes and ponds are less abundant than on the coastal plain and are primarily glacial kettles rather than thaw lakes. The foothills have been affected by four major glacial events that left distinctive landscapes: (1) Gunsight Mountain, probably greater than 1.2 million years; (2) Anaktuvuk, about 250,000 years; (3) Sagavanirktok, about 125,000 years; and (4) Itkillik, about 8,000 to 12,000 years (Detterman et al. 1958; Porter 1964; Hamilton 1986). The foothills have traditionally been divided into a southern and a northern region (Wahrhaftig 1965). The Northern Foothills have the older glaciated surfaces, with more rolling topography, fewer kettle lakes, and more uniform vegetation cover. The Southern Foothills have more topographic variety with distinctive glacial terrain and many sandstone outcrops of the Fortress Mountain and Torok formations and other sandstone, siltstone, and shale formations (Payne et al. 1951; Keller et al. 1961; Hamilton 1986; Walker et al. 1989).

The foothills climate is highly variable and more continental than the coastal areas, with some of the warmest summer temperatures on the North Slope and some of the coldest winter temperatures (Table 1). Mean annual temperature ranges from -7°C to -11°C, and total precipitation is 140 to 267 mm. Summer air temperature ranges from 5°C to 14°C. Thawing degree-days, which is the sum of °C above 0°C for all days when the mean temperature is above 0°C and represents a measure of total seasonal warmth, ranges from 760°C to 1125°C (Haugen 1982).

The dominant foothills vegetation is tussock sedge tundra, but there are a variety of other plant community types related to surface age, bedrock type, periglacial surface forms, exposure, drainage, topography, and alkaline loess (Churchill 1955; Bliss and Cantlon 1957; Spetzman 1959; Koranda 1960; Cantlon 1961; Wiggins and Thomas 1962; Hettinger and Janz 1974; Racine and Anderson 1979; Racine 1981; Walker et al. 1982; Walker 1988). Tussock sedge tundra, dominated by the cottongrass *Eriophorum vaginatum*, ericaceous shrubs, dwarf birch, and *Sphagnum* moss, is of particular interest because it covers most gentle hillslopes in acidic, non-loess-affected regions of the foothills, and represents a transition between upland, non-wetland areas and marshy, lowland areas. The characteristic tussock growth form of *Eriophorum vaginatum* creates considerable microtopographic diversity, and foothills slopes appear hummocky primarily because of this species. Nutrient and production dynamics of tussock tundra have been the focus of numerous studies (Tamm 1954; Chapin 1972; Chapin et al. 1979, 1986; Miller et al. 1984; Mark et al. 1985; Shaver et al. 1986a, b).

The Imnavait Creek site is a good representative of acidic tundra on Sagavanirktok-age surfaces in the Southern Foothills Province (Figure 2). Walker et al. (1989) have described the physiography of the site. The hills around Imnavait Creek are mostly gently rolling, rising less than 100 m from the valley bottoms to the ridge crests, and elongated in a NNW direction. Two lines of more steeply rounded sandstone and shale outcrops of the Fortress Mountain Formation are oriented perpendicular to Imnavait Creek. The maximum elevation within the watershed is about 945 m, and the lowest elevation along Imnavait Creek is about 875 m. The local hills are covered by glacial till of the Sagavanirktok River Glaciation (Middle Pleistocene) (Detterman et al. 1958; Hamilton 1986). These deposits are sufficiently fresh that most hill crests have till at the surface, providing rocky mineral substrate for plant communities, whereas hill slopes and valley

Table 1. Comparison of climate data for the physiographic provinces (from Haugen 1982).

	Coastal Plain	Foothills	Brooks Range
Degree-day totals (°C)			
Thawing	318-897	760-1125	453-1189
Freezing	4409-5642	4225-5412	3173-3888
Thaw season			
Length of thaw (days)	91-128	104-139	87-131
Starting date	25 May-9 Jul	18 May-27 June	3 May-10 June
Precipitation (mm)			
Frozen	125-142	87-110	57-181
Unfrozen	58-81	52-157	117-292
Total annual	183-229	140-267	295-450
Temperature (°C)			
Mean annual	-12.8 to -10.3	-11.1 to -6.7	-6.9 to -5.9
Mean annual diurnal range	7.2 to 9.6	7.6 to 11.6	10.8 to 12.6
Annual temp. range (extreme low-high)	-50.6 to +28.9	-53.3 to +30.0	-37.8 to +26.1

bottoms are generally smoothly eroded and covered by colluvium and shallow peat deposits. This contrasts markedly with terrain of a nearby lobe of Itkillik (Late Pleistocene) till in the Sagavanirktok River valley, where deposits are generally quite stony and little eroded (Walker et al. 1989).

Terrain Units

Although hillslope deposits dominate the foothills, there are other common terrain units at Imnavait Creek and elsewhere in the foothills that exert influence on vegetation and soils. The terrain unit classification presented here was developed by Kreig and Reger (1982) for the foothills and summarized by Walker et al. (1989) for Imnavait Creek, where they described five units: bedrock outcrops, till deposits, retransported hillslope deposits, basin colluvium, and floodplains (Figure 3). Superimposed on the various terrain units are periglacial surface forms such as frost scars, ice-wedge polygons, and stone stripes.

Bedrock outcrops. Several small steep-sided hills in the Imnavait Creek area are formed from the Fortress Mountain sandstone formation (Chapman et al. 1964; Brosgé et al. 1979). Although they cover only about 1% of the mapped area, they add considerable topographic and floristic diversity (Walker et al. 1989). The Fortress Mountain formation is Lower Cretaceous and composed predominantly of shale and siltstone (Chapman et al. 1964). Outcrop surfaces range from smooth gravelly slopes on south-facing exposures to talus on steep north-facing exposures. The south-facing slopes remain largely snow-free in winter, and the north-facing slopes accumulate deep snow drifts. Flat areas on rock outcrops have frost scars (Everett 1980a). These features have also been termed nonsorted circles, frost boils, and mud hummocks (Washburn 1956, 1973; Mackay and MacKay 1976).

Figure 2. The Imnavait Creek site, looking south toward the headwaters of Imnavait Creek. The feature in the foreground is a materials site for the Dalton Highway. Note the gradual change in tone down the hillslope. D.A. Walker photo no. 84-39-24.

Till deposits. About 9% of the area in Figure 3 is covered by glacial till. The till source is from two different-aged glaciations, the Itkillik (late Pleistocene) and Sagavanirktok (middle Pleistocene). The Sagavanirktok till covers most hillslopes and is clay-rich, with considerable amounts of Kanayut Conglomerate from the Brooks Range (Hamilton 1986; Walker et al. 1989). Sagavanirktok till deposits at Imnavait Creek are generally exposed only on ridge crests. Most hillslopes are covered by retransported colluvial material, with only occasional erratics indicating the underlying till deposits. Frost scars (Everett 1980a) and blockfields (Washburn 1973) are common on till deposits.

Retransported hillslope deposits. These overlie much of the Sagavanirktok till and are the dominant terrain unit at Imnavait Creek and throughout the foothills. About 70% of the mapped area is covered by these deposits, which Kreig and Reger (1982) describe as "relatively fine-grained organic-rich materials moved downslope by slopewash, solifluction and piping. This unit commonly contains massive ice." At Imnavait Creek, till sheets are covered by clay loam that has been retransported downslope and that supports tussock sedge tundra vegetation (Walker et al. 1989). Surface forms on retransported hillslope deposits include water tracks (described below), frost scars, and nonsorted stone stripes. Stone-stripe complexes often grade into water-track complexes (Everett et al. 1989). Stone-stripe complexes are "patterned ground with a striped pattern and a nonsorted appearance due to parallel lines of vegetation-covered ground and intervening strips of relatively bare ground oriented down the steepest available slope" (Washburn 1956). At Imnavait Creek, the stony dry element of the stripes is 1.5 to 2 m wide, with frost scars and well-developed hummocks. Interstripe areas are wet and peaty (Walker et al. 1989).

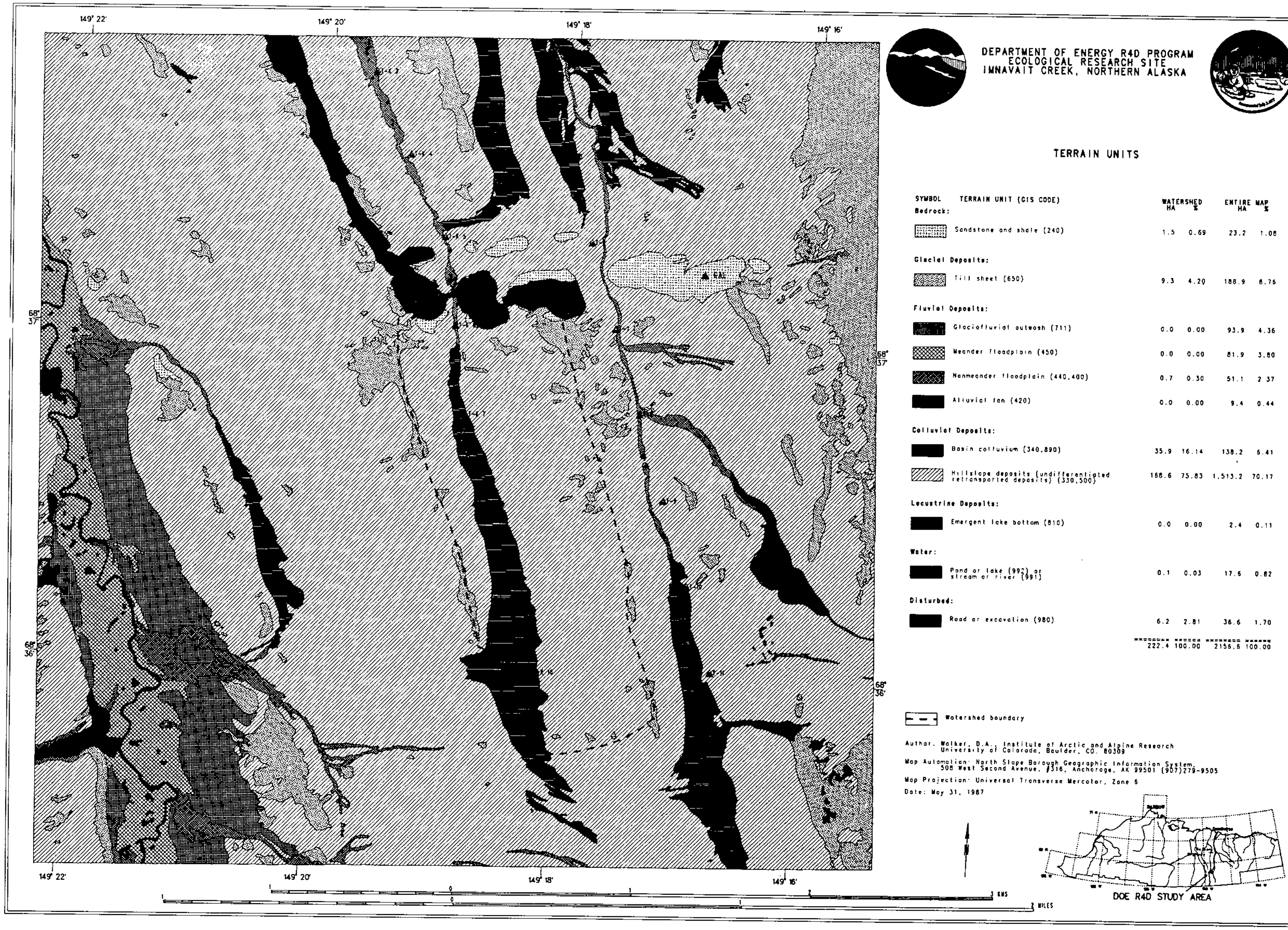


Figure 3. Terrain units of the Imnavait Creek area, from Walker et al. (1989).

Most of the retransported hillslope deposits contain hillslope water tracks, which are "shallow channels that conduct snow meltwater and subsurface water during the thaw season giving the topography a ribbed appearance" (Walker et al. 1989). Hillslope water tracks are generally subparallel channels spaced several tens of meters apart, although their density varies across the region. Most hillslope water tracks in the Imnavait Creek watershed are shallow with indistinct drainage channels, but well defined water tracks are also present. These hillslope water tracks are different from the water tracks described in mires of Minnesota, Labrador, and northern Europe (Heinselman 1970; Glaser et al. 1981; Glaser 1983), where the term implies minerotrophic drainage tracks in lowlands through generally flat peatlands. We therefore make the distinction between hillslope water tracks and lowland water tracks. Although hillslope water tracks are the most common form throughout the foothills, lowland water tracks occur in most colluvial basins.

Basin colluvium deposits. About 6% of the Imnavait Creek site is mapped as basin colluvium. These deposits occur at the headwaters of most small foothill streams, where they collect water from weakly defined drainage channels on the surrounding slopes (Kreig and Reger 1982; Walker et al. 1989). The deposits of these features are:

> ...generally fine-grained, organic-rich deposits with variable amounts of granular material present in basins occurring between smoothly rounded slopes on the Arctic Slope. They are usually associated with frozen upland silt. The origin of this landform is not definitely known. However, the material appears to have moved into small basins from surrounding slopes by solifluction, creep, and/or slopewash. Other processes that could have a role in the genesis of this deposit are thaw basin formation and drainage, organic deposit development, and perhaps eolian deposition. Basin colluvium is differentiated from thaw lake materials by smooth gradation with surrounding slopes and the highly variable and thin character of accumulated deposits (R. Kreig, Kreig and Assoc., Denver; pers. comm.).

Microtopography of the basins is complex consisting of raised features such as strangs (raised hummocks aligned in sinuous strings perpendicular to the line of drainage), palsas (small ice-cored mounds), and high-centered ice-wedge polygons (Walker et al. 1989). Wet areas have lowland water tracks [in the sense of Glaser (1983)], flarks (ponded depressions between raised strangs in strangmoor complexes), wet meadows, and thermokarst pits (deep water-filled pits caused by local thaw of ice-rich permafrost) (Walker et al. 1989). These peatlands often have raised ombrotrophic microsites that are not in contact with water flowing through the basins and the minerals that the water carries (Sjørs 1948, 1963; Drury 1956; Damman 1977, 1986; Heinselman 1963, 1970; Glaser et al. 1981; Glaser 1983; Foster and Glaser 1986). *Sphagnum*-rich bog vegetation occurs on raised surfaces in colluvial basins at Imnavait Creek, and poor-fen species, such as *Carex rotundata, C. rariflora, Eriophorum scheuchzeri*, and *Sphagnum lindbergii*, occur in lower microsites, indicating relatively minerotrophic conditions.

Floodplain deposits. These are important wetland areas that cover about 11% of the Imnavait Creek site (Walker et al. 1989). There are two distinctive floodplain types within the mapped area: the large meandering Kuparuk River and beaded streams represented by Imnavait Creek. The Kuparuk River has its headwaters in the Southern Foothills and is a major river draining that part of the North Slope. The beaded streams are chains of small ponds formed where the stream has eroded and melted massive ground-ice deposits. Stream margins are predominantly peaty, with occasional sections of stony banks.

Hydrology and Geochemistry

The majority of hydrologic research in northern Alaska has focused on the coastal plain (Brown et al. 1968; Holmgren et al. 1973; Kane and Carlson 1973; Dingman et al. 1980; Drage et al. 1983; Everett 1983), with relatively little research in the foothills. Research at Imnavait Creek (Everett and Ostendorf 1988; Kane and Hinzman 1988; Everett et al. 1989) is among the first to characterize the hydrologic and geochemical regimes in the foothills.

Three primary factors influence the hydrology and geochemistry at Imnavait Creek: (1) the timing and duration of snowmelt, (2) the presence of a peat layer on all but the most exposed surfaces, and (3) the presence of hillslope water tracks. Both surface and stream hydrology of the Imnavait Creek watershed are dominated by snowfall distribution and the brief snowmelt flood in spring (Everett and Ostendorf 1988; Kane and Hinzman 1988). In 1986, stream discharge began 4.5 days after the mean daily temperature rose above 0°C and peaked 84 hours later at 515 l/sec (Everett and Ostendorf 1988). The result of this rapid activity was that about 50% of total annual streamflow occurred in an 8 day period. This nival (dominated by snow) hydrologic regime is typical of many arctic regions (Woo 1982; Everett and Ostendorf 1988).

Correlations between snow gauge measurements and end-of-season snow water equivalent measurements indicate that Wyoming snow gauges (Benson 1982) fairly accurately represent winter precipitation minus ablation (Liston 1986). About 50% of the effective precipitation (end-of-winter water equivalent) at Imnavait Creek falls as snow, and total annual precipitation is about 350 mm (Everett and Ostendorf 1988). Snowmelt begins in late May or early June, and hydrologic activity ceases in mid-September, when surface flow ceases.

At the time of meltoff, only the top few centimeters of ground are thawed. *Sphagnum* and other mosses in this top layer have a large water storage capacity. This is due in part to the presence of large hyaline cells (Boelter 1970) that have low turgor in early spring due to sublimation, but which fill rapidly during the snowmelt period. Because only a few centimeters of the moss layer are thawed and able to absorb the runoff waters, most of the water released from the snowpack either runs off or evaporates (Kane et al. 1978; Kane and Slaughter 1983). Redistribution of snow due to wind prior to meltoff and spatial variation in soil texture and water-holding capacities results in considerable spatial variability in percentages of runoff and evaporation losses during snowmelt (Hayward and Clymo 1982; Alpert and Oechel 1984; Kane and Hinzman 1988). Hydraulic conductivity of peats can vary by a factor of five depending on botanic origin and degree of decomposition (Boelter 1965, 1972; Ford and Bedford 1987; Kane and Hinzman 1988). At Imnavait Creek, areas with the deepest snow water equivalent have the highest percentage of melt-period runoff, and areas with the least snow cover have the highest percentage of evaporation. Runoff during the meltoff period varies between 21% and 79% of the water released from the snow, and evaporation varies between 10% and 63%. Soil storage is low in all cases, from 10% to 15% (Kane and Hinzman 1988). These numbers are consistent with those reported in other arctic areas. For example, in the Mackenzie Delta in northwestern Canada, 85% of the snowmelt water goes into runoff (Anderson and MacKay 1974).

Fifty percent of the precipitation at Imnavait Creek falls as summer rains. Storms are generally of low intensity, but one or two high intensity (72 mm/hr) storms have been recorded each summer. During low intensity storms, soil storage capacity is sufficient that there is little lateral downslope movement of water. Once the storage capacity of the organic layer is exceeded, which often occurs during high intensity storm events, water may move laterally downslope

through the moss canopy. The major flow periods in water tracks are also during meltoff and intense storm events (Everett and Ostendorf 1988).

The hydrologic regime at Imnavait Creek strongly affects the geochemistry of the site. Times of peak discharge coincide with maximum pH, maximum electrical conductivity, and peak concentration of dissolved and particulate organics (Oswood and Flanagan 1987; Everett and Ostendorf 1988; Everett et al. 1989). Ionic concentrations in stream waters are low and fluctuate daily. Most ions originate as dryfall, with the exception of potassium, which has a local botanic origin. Sulfate has a noticeable seasonal trend; it is present in only trace amounts during the melt period, and it reaches a peak in late season as soils thaw to a maximum depth and oxidation potential is highest (Everett and Ostendorf 1988).

METHODS

Vegetation and soil analyses were conducted as part of the DOE R4D research. The information summarized here is from two primary sources: (1) 73 permanent plots that were distributed among the major vegetation units and used for vegetation mapping (Walker et al. 1987, 1989), and (2) 21 plots located along two toposequences on representative west-facing hillslopes (Walker and Lederer 1987).

FIELD DATA

Permanent Plots

Data on species composition and abundance were collected from 73 locations within the study area using the centralized replicate method (Mueller Dombois and Ellenberg 1974). Sampling was completed during 1-10 August 1984 and 17 August to 4 September 1985. Plot locations were chosen to represent major vegetation communities present at the site. Data collected from these locations are referred to as permanent plot data.

Vegetation. Vegetation plots consisted of 5-m radius circles and were numbered consecutively from SW1 to SW73. Eleven plots contained two distinct homogeneous vegetation units associated with small microtopographic elements such as frost scars, stone stripes, or hummocks. In these cases, data from each element were kept separate and given a suffix of A or B. Thus, there were a total of 84 vegetation samples.

Visual estimates of percentage cover were made for all vascular, bryophyte, and lichen species within each plot. A small sample of each species was collected and returned to the laboratory for final identification. Identifications were verified by Drs. David and Barbara Murray of the University of Alaska. Voucher specimens were deposited in the University of Alaska Herbarium at Fairbanks. Nomenclature follows that used by the University of Alaska Herbarium.

Soils. A soil pit was dug immediately adjacent to each vegetation sample, and the soil was described and classified to the level of subgroup using USDA standard methods (Soil Survey Staff 1975). Soil samples were collected from each horizon in plots SW1 - SW62 and SW65 and from 10 cm depth in plots SW67, SW72, and SW73. Plots SW63 and SW64 were in a boulder field and did not have any soil; plot SW66 is a deep aquatic site, and its soil was not described.

Site factors. Site variables, including thaw depth, site moisture regime, and 1986 pre-meltoff snow depth, were collected at each sampling location. The full list of site variables is in Table 2.

Table 2. List of site factors for each permanent plot.[a]

Environmental variables	Soil chemical variables
Slope (°)	pH
Aspect (° from north)	Ca^{+}
Exposure to winds (1-4 scalar)	Mg^{+2}
Site moisture (1-10 scalar)[b]	K^{+}
Snow depth (cm, May 1986)	Mn*
Snow duration (1 to 5 scalar)	P*
Stability (scalar)	Total Fe*
Cryoturbation (percent)	Fe^{+2}*
Microrelief height (cm)	Fe^{+3}*
Thaw depth (cm)	Fe-exchangeable*
Bare soil cover (cm)	Zn^{+}
Rock cover (percent)	NH_4^{+}

[a] Data collected for only a subset of plots are marked with a *.
[b] Scalar value based on amount of water that could be squeezed from soil.

Toposequences

In addition to the permanent plot samples, two soil-vegetation toposequence transects were sampled in August 1986 on a gentle, west-facing slope (Walker and Lederer 1987). Transect 1 was about 650 m long and had 12 sampling locations. Transect 2 was about 550 m long and had 9 sampling locations. Data collected from these sites are referred to as toposequence data.

Vegetation. Vegetation sampling was different than in the permanent plots because here we were interested in quantitative differences in species abundance along the hillslope, whereas the vegetation classification is based primarily on presence or absence of species and subjective estimates of cover (Mueller Dombois and Ellenberg 1974). At each sampling location, a 10-m tape was stretched perpendicular to the fall line, with its center on the transect. Five point quadrat frames were sampled along this tape. The point quadrat frame was 0.5 x 1 m, with intersecting sets of string every 10 cm, resulting in a total of 50 points per quadrat. At each point, the top plant in the vegetation canopy was recorded as a "hit." Data from the five quadrats were combined, resulting in 250 points per sampling location. Percentage cover for each plant species at the sample location was calculated according to Equation (1).

$$\text{Percentage cover} = \frac{\text{number of hits}}{250} \qquad (1)$$

Soil. Soil was described and classified from a pit located at the center of the sampling location. Soil samples were collected from each horizon below the Oi horizon and returned to the laboratory for analysis.

Interstitial water. In 1988, tension lysimeters were installed at 10 of the 12 sampling locations on Transect 1 in order to describe the geochemical catena associated with the slope. Two lysimeters were installed at each location: (1) a short (30 cm) sampler was placed in the B horizons (or in an O horizon in the case of organic soils), usually between about 14 and 20 cm depth; (2) a long (61 cm) sampler was placed at the contact between the active layer and the permafrost zone, which was usually at about 40 cm depth. At the upper slope positions permafrost was too deep to reach with the long samplers, so these were placed at 40 cm depth. Short samplers characterize the zone of most active solute transport during periods of saturation, and long samplers generally characterize the permafrost boundary zone. Permafrost represents an impermeable barrier at the base of all these soils, and thus water will flow along this zone rather than downward to a groundwater table.

Lysimeters were sampled on 25 August, 28 August, and 1 September 1988 by applying about 60 centibars of suction. Samples were frozen and shipped to The Ohio State University for chemical analysis.

LABORATORY ANALYSIS

Permanent Plot Samples

Soils collected from permanent plots were analyzed for percentage organic matter, particle size, hygroscopic moisture, and bulk density. Only the horizon within the primary rhizosphere (about 10 cm depth) was analyzed for particle size and bulk density, except in cases where these data were necessary for proper classification. Additionally, pH, Ca^{+2}, Mg^{+2}, and K^{+} were determined for each horizon, and NO_3^- was determined from the rhizosphere.

Hygroscopic moisture was determined by calculating percent weight loss of air-dried soil after oven drying at 105°C for 24 hr. Organic matter was determined by the Walkley-Black procedure (Nelson and Sommers 1982). Particle size was determined by using sieves to separate sand, and then separating silt and clay with the pipet method (Gee and Bauder 1986). Bulk density was calculated as weight of oven-dried soils (105°C for 24 hr) divided by sample volume. Soil pH was determined with the saturated paste method (Jackson 1958) using a Chemtrix Type 400 pH meter. Cations were extracted using the ammonium acetate method (Thomas 1982). Filtrate was analyzed using a Perkin-Elmer Atomic Absorption Spectrophotometer Model no. 2280. NO_3^- was extracted with KCl (Keeney and Nelson 1982) and analyzed on a Dionex 2010i Ion Chromatograph (Dick and Tabatabai 1979).

Toposequence Samples

Soil. Soil toposequence samples were treated identically to samples from permanent plots, with the exception that total P ($H_2PO_4^-$ + HPO_4^{-2} + PO_4^{-3}) was determined for each horizon, and SO_4^{-2} was determined for the soil horizon at 10 cm depth. These were both extracted using the Bray 1 method (J. McKendrick, University of Alaska Palmer Plant and Soils Laboratory; pers. comm.) with an extracting solution of 0.03N NH_4F adjusted to pH 2.6 using HCl. Filtrate was analyzed with a Dionex 2010i Ion Chromatograph.

Interstitial water. Soil interstitial water was analyzed for pH, electrical conductivity, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, and total dissolved Mn, Fe, F^{-}, Cl^{-}, HPO_4^{-2}, NO_3^{-}, and SO_4^{-2}. Solution pH was measured with a Beckman SS-2 pH meter; electrical conductivity was measured with a YS1 model 31 conductivity bridge. Extreme pH or conductivity samples were repeated. Cation samples were acidified with HNO_3 and stored in a cold room until analysis. A Perkin-Elmer 3030B Atomic Absorption Spectrophotometer was used for cation analysis. Anion samples were filtered and measured using a Dionex 2000i ion chromatograph equipped with a fast column.

DATA ANALYSIS

Vegetation Classification

Vegetation data from permanent plots were used to develop a hierarchical, table-based classification using the method of Braun-Blanquet (1932) as described by Mueller-Dombois and Ellenberg (1974) and Westhoff and van der Maarel (1978). Three informal levels were recognized in the hierarchy: groups, subgroups, and community types. The community type is the basic classification unit, and corresponds approximately to the association of Braun-Blanquet, although several community types lack good differentiating species and therefore may correspond more closely to subassociations. Subgroups and groups are likely equivalent to alliances or higher levels (orders and classes) in the Braun-Blanquet system. The Imnavait Creek classification is not formalized due to the lack of published information for the North Slope regional and the small number of plots used to define each type. Formal definition and recognition of these within the Braun-Blanquet system of classification will require more extensive sampling, with complete species lists from a larger region of the foothills.

Wetland Indices

Calculation by sample. Calculation and testing of wetland indices followed the method outlined by Wentworth and Johnson (1986), which is basically a weighted averages ordination (Whittaker 1948). The method involves assigning each species a value from 1 to 5 corresponding to its wetland indicator status in the list of wetland plant species for Alaska (Reed 1988). This classification system has five categories: obligate wetland, facultative wetland, facultative, facultative upland, and obligate upland (Table 3). The result of the weighted averaging is that each sample is assigned a wetland indicator value between 1 and 5 that summarizes the wetland indicator categories of its species. Samples with primarily obligate and facultative wetland species will have low index values; samples with primarily upland species will have high index values. The detailed steps in this analysis were as follows:

(1) Each vascular species was assigned a numeric wetland indicator status based on Reed (1988, column RAIND), using the conversion in Table 3. Species not listed in Reed (1988) were placed into a provisional category based on the knowledge and experience of the authors. Four of the species not in Reed (1988) were classified as facultative upland; the remaining 25 were classified as upland. Appendix A lists the species and their status.

(2) Because of the importance of cryptogamic species in this ecosystem, all cryptogams present in the permanent plots were also provisionally assigned a wetland indicator status. Determinations were based on a combination of field experience and literature. Nyholm (1954),

Table 3. Wetland indicator categories (Reed 1988) for plant species and corresponding numeric values (Wentworth and Johnson 1986).

Category	Code	Numeric value	Frequency in wetlands[a]
Obligate	OBL	1	>99%
Facultative wetland	FACW	2	67% - 99%
Facultative	FAC	3	34% - 66%
Facultative upland	FACU	4	1% - 33%
Upland	UPL	5	<1%

[a] This value represents the percentage of total occurrences of the species within Alaska that are in wetlands.

Steere (1978), Steere and Inoue (1978), Andrus (1984), and Crum (1984) were used for the bryophytes. Thomson (1979, 1984) was the source for lichen species. Cryptogam species with primary substrates other than soil (corticolous, epiphytic, saxicolous, and dung species) were excluded from the analyses. Bryophytes and lichens were each treated as separate canopy components.

(3) Cover values were converted to the midpoint ranges of Daubenmire (1968) cover classes (Table 4).

Table 4. Daubenmire (1968) cover classes and midpoints used in the index calculations.

Cover class	Percent cover range	Midpoint
1	0 - 5	2.5
2	6 - 25	15.0
3	26 - 50	37.5
4	51 - 75	62.5
5	76 - 95	85.0
6	96 - 100	98.0

(4) A weighted average value for each sample was calculated according to the equation:

$$WA_j = \frac{\sum_{i=1}^{n} I_{ij}E_i}{\sum_{i=1}^{n} I_{ij}} \tag{2}$$

where WA_j is the weighted average for sample *j*, n is the number of species in a given sample, I_{ij} is the Daubenmire cover class value for species *i* in sample *j*, and E_i is the ecological index value (wetland indicator status from Table 3) for species *i*. Each canopy component (vascular plants, bryophytes, and lichens) was analyzed separately, as were all layers together.

(5) A simple (unweighted) index average for each sample was also calculated according to the equation:

$$A_j = \frac{\sum_{i=1}^{n} E_i}{n} \tag{3}$$

where A_j is the index average for stand *j*. Canopy components were treated in the same manner as for the weighted averages.

(6) Analysis of variance was used to test for differences in weighted and index averages among soil types and vegetation classes. Duncan's multiple range test was used to determine which types were significantly different.

Calculation by species. A second set of averages was used to determine if any species listed by Reed (1988) might be incorrectly classified in terms of wetland indicator status. The vascular index averages from each sample were used to calculate new index averages for each species. This is conceptually related to reciprocal averaging ordination (Gauch 1982), because one set of averages is used to calculate a new set. These calculated species indices are referred to as species index averages. The steps in calculation of species index averages were:

(1) Each sample is assigned an index average calculated according to Equation (3).

(2) A species index average is then calculated for each species according to the equation:

$$A_i = \frac{\sum_{j=1}^{m} A_j}{m} \tag{4}$$

where A_i is the species index average value for species *i*, m is the number of samples in which the species occurs, and A_j is the simple average for stand *j*. If a calculated value of A_i deviates by at least 1.0 from the values determined from Reed (1988), then review of that species' status is recommended, because at least at this site it is tending to occur more frequently in samples with average values that differ from its assigned value.

Correlation with Independent Wetness Measures

Pearson product-moment correlations between weighted and index averages and independent measures of wetness were calculated to determine how the averages were related to soil moisture. Wetness variables were field estimates of soil and site moisture and 1986 end-of-season snow depth measurements.

RESULTS

SOIL

Seven soil subgroups, contained within six great groups and three orders (Soil Survey Staff 1975), were identified from the permanent study plots (Table 5). These are listed in order of the SCS classification, which does not represent the moisture gradient of the site but rather the major genetic and environmental factors influencing soil development and processes. Four of the seven subgroups are listed as hydric according to an informal classification developed by Everett (1984) for Alaskan tundra regions using the subgroup as the lowest level of soil information (Table 6). An additional subgroup, Hemic Pergelic Sphagnofibrist, is not listed in the classification but has the necessary characteristics for a hydric soil.

Table 5. Soils of the Imnavait Creek study area.

Order	Great group	Subgroup	Number of occurrences
Histosol	Cryofibrist	Pergelic Cryofibrist	3
	Sphagnofibrist	Hemic Pergelic Sphagnofibrist	3
	Cryohemist	Pergelic Cryohemist	5
Entisol	Cryorthent	Pergelic Cryorthent	4
Inceptisol	Cryaquept	Pergelic Cryaquept	28
		Histic Pergelic Cryaquept	20
	Cryochrept	Pergelic Cryochrept	16

The overwhelming importance of permafrost in these soils is indicated by the Pergelic adjective that is attached to all of the subgroups. The soils can be immediately divided into two broad groups: organic soils, represented by the Histosol order, and mineral soils, represented by all other orders. Histosols are defined (Soil Survey Staff 1975) as "soils that are dominantly organic. They are mostly soils that are commonly called bogs, moors, or peats and mucks." Most

Histosols are saturated throughout the growing season. This is the case at Imnavait Creek, where the Histosols are all considered hydric soils.

Table 6. Wetland soils of northern Alaska (Everett 1984).

Order	Suborder	Great group	Subgroup
Mollisol	Aquoll	Cryaquoll	Pergelic Cryaquoll
Inceptisol	Aquept	Cryaquept	Pergelic Cryaquept Histic Pergelic Cryaquept
Histosol	Saprist Hemist Fibrist	Cryosaprist Cryohemist Cryofibrist	Pergelic Cryosaprist Pergelic Cryohemist Pergelic Cryofibrist

Histosols

Histosols at Imnavait Creek are either Fibrists or Hemists. Pergelic Cryofibrists (Figure 4) are found in the wettest sites, generally in ponds or along pond margins. They consist almost entirely of the undecomposed root material of aquatic plants. Hemic Pergelic Sphagnofibrists (Figure 5) are differentiated by the dominance of fibric organic materials derived primarily from Sphagnum mosses. The Hemic adjective indicates that although these soils are dominated by fibric materials, they are more decomposed than most Fibrists and grade toward Hemists. These soils are not extensive at Imnavait Creek. They occur in ombrotrophic colluvial basins where Sphagnum mosses are most abundant. Although Sphagnofibrists are not included in Everett's (1984) classification, the hydrologic regime of the colluvial basins would indicate these should be classed as hydric. Pergelic Cryohemists are the final organic soil type at Imnavait Creek (Figure 6). They are found in similar topographic situations to Hemic Pergelic Sphagnofibrists, and the two types grade into one another.

Entisols

Entisols are soils with little or no evidence of development (Soil Survey Staff 1975). They are defined as mineral soils, with essentially no horizon development or presence of defining characteristics. Entisols are defined primarily on the basis of what they are missing rather than the presence of specific characteristics. The primary Entisols at Imnavait Creek are classified as Pergelic Cryorthents. Orthents are usually found on newly exposed surfaces or erosional surfaces. Pergelic Cryorthents are distinguished from other Orthents solely on the basis of temperature. At Imnavait Creek, Pergelic Cryorthents occur on south-facing sandstone outcrops and on Itkillik-age till. These are all dry sites, and these are considered upland soils.

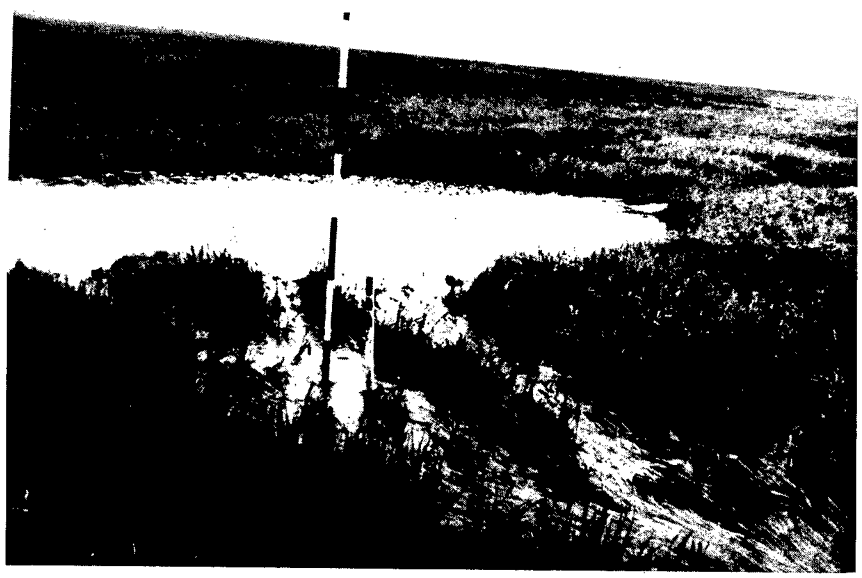


Figure 4. A Pergelic Cryofibrist soil. The vegetation is dominated by *Carex aquatilis*. Note the many visible fibers within the soil profile. This profile is described in Appendix B-1. Soil photo D.A. Walker no. 84-43-14; site photo D.A. Walker no. 84-43-17.

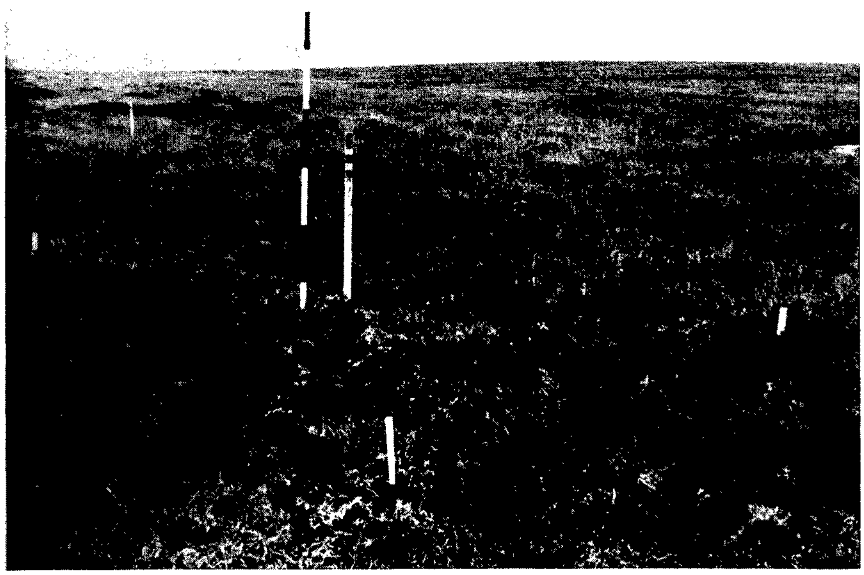
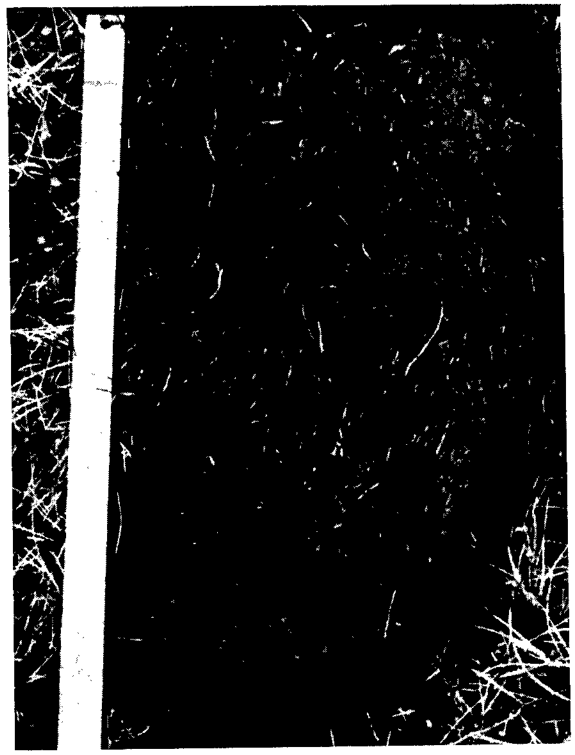


Figure 5. A Hemic Pergelic Sphagnofibrist soil. Note the abundance of *Sphagnum* moss fibers throughout the profile and in the surrounding vegetation. This site is within a colluvial basin. The raised features are palsas (ice-cored mounds). This profile is described in Appendix B-2. Soil photo D.A. Walker no. 84-44-9; site photo D.A. Walker no. 84-44-10.



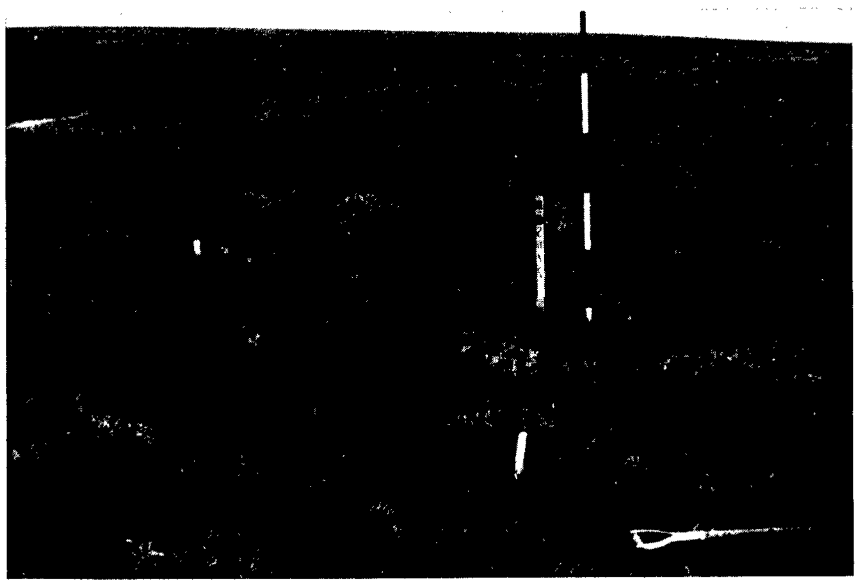


Figure 6. A Pergelic Cryohemist soil. Note the standing water. This site is in a lowland water track area. This profile is described in Appendix B-3. Soil photo D.A. Walker no. 84-44-1; site photo D.A. Walker no. 84-44-2.

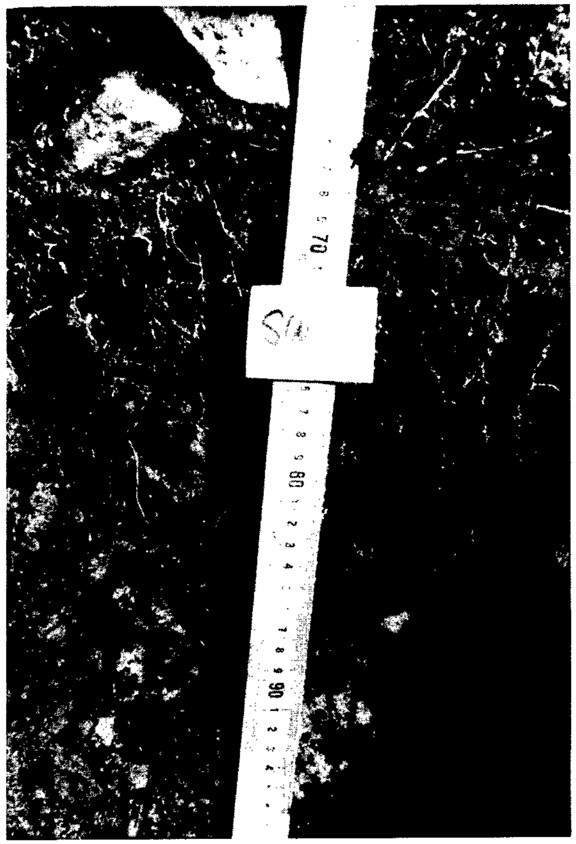
Inceptisols

Inceptisols are spatially the most extensive soil order at Imnavait Creek. Inceptisols are moderately weathered soils of humid regions (Soil Survey Staff 1975). In northern Alaska, Inceptisols grade into Histosols, Entisols, and Mollisols. They are distinguished from Histosols by being mineral, that is, they do not meet the criteria for an organic soil. They are distinguished from Entisols by the presence of at least a cambric (weathered) horizon, and from Mollisols by relatively low base saturation. In foothill areas where calcareous loess is a factor, Inceptisols become less common and are replaced by Mollisols, which have a higher base saturation and therefore greater availability of nutrients (Everett 1984). The different nutrient regimes in the Mollisols allow them to support vegetation that is floristically distinct from the more-acidic, less-base saturated Inceptisols, even though certain soil types that fall into the two different orders are not morphologically distinguishable (Walker and Acevedo 1987). Imnavait Creek is predominantly acidic, with little influence by calcareous loess, and Mollisols are therefore absent.

Ochrepts and Aquepts are the two primary suborders of Inceptisols at Imnavait Creek. Pergelic Cryochrepts are non-hydric soils of upland areas (Figure 7). Ochrepts are "the light colored, brownish, more or less freely drained Inceptisols of mid to high latitudes" (Soil Survey Staff 1975). This is the dominant soil type of upland areas at Imnavait Creek. Pergelic Cryochrepts support a diverse vegetation cover, with an abundance of ericaceous shrubs.

The Aquepts, as their name implies, are the wettest Inceptisols. They have an aquic moisture regime and may have a histic (organic) epipedon. Although the presence of an aquic moisture regime is often difficult to establish, the frequent presence of mottles in these soils has generally been considered sufficient evidence to support an aquic moisture regime in northern Alaska (Everett 1980b, 1984). The two Aquepts at Imnavait Creek are both Pergelic Cryaquepts, with one subgroup differentiated by the presence of a histic epipedon and therefore called a Histic Pergelic Cryaquept. These are the soils of the gentle hillslopes that cover most of the foothills. They support extensive areas of tussock tundra that characterize much of the foothills. They are spatially the most extensive soils at Imnavait Creek. Although they are mineral soils, originally classified as Tundra Soils by Tedrow (1977), they grade into the Histosols. The basic concept of this soil is an organic surface horizon overlying a gleyed mineral (B) horizon. The boundary between these horizons is usually abrupt (Everett et al. 1981). If annual production exceeds decomposition, the organic layer will increase in thickness over time. Pergelic Cryaquepts are the drier and less organic of the two types and are found primarily in upper slope positions (Figure 8). They grade downslope into Histic Pergelic Cryaquepts (Figure 9). Because of their wide areal extent and variety of habitats where they occur, the moisture status of these soils is often difficult to establish by field observation. Both Pergelic Cryaquepts and Histic Pergelic Cryaquepts are considered hydric soils by definition.

Pergelic Cryaquepts on frost scars are given the antecedent 'Ruptic', which indicates evidence of cryoturbation (mixing by frost action). Frost scars and inter-frost-scar areas have associations of soils, usually with Pergelic Cryaquepts between the frost scars and Ruptic Pergelic Cryaquepts in the centers of the frost scars. These types were combined for the analyses here because of their close spatial relationship. They are mapped as a single unit (Everett 1980b).



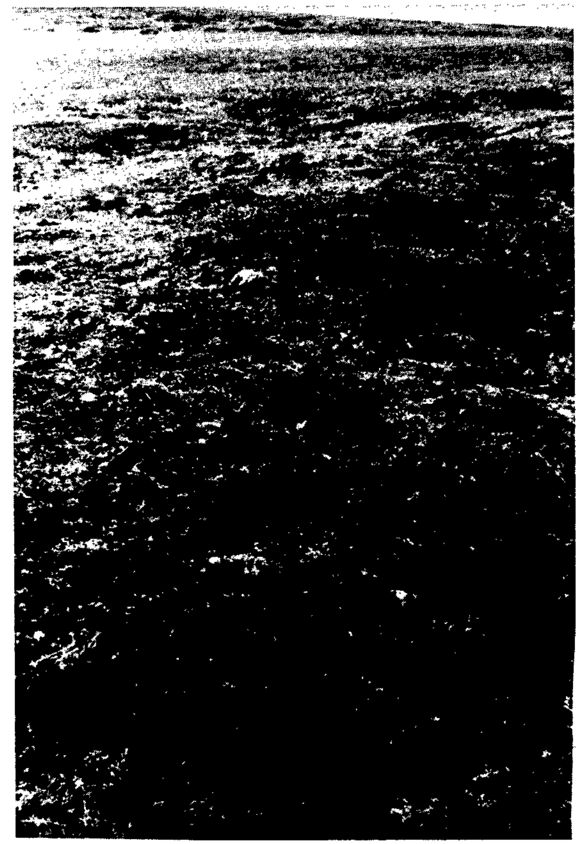


Figure 7. A Pergelic Cryochrept soil. This soil type is characterized by a sapric organic horizon over a cambic (weathered) B horizon. Note the large gravels in the mineral horizon. This site is on a ridge crest dominated by ericaceous shrubs. This profile is described in Appendix B-4. Soil photo D.A. Walker no. 84-46-24; site photo D.A. Walker no. 84-46-22.

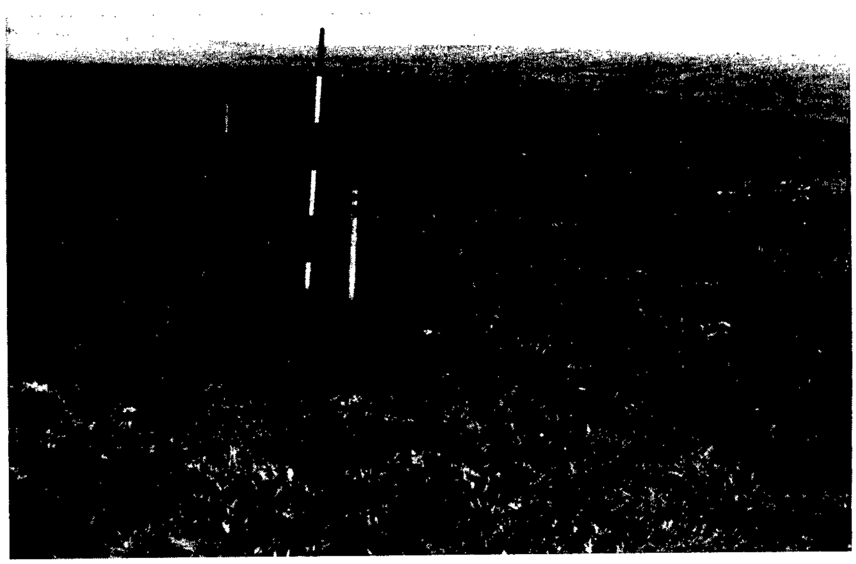


Figure 8. A Pergelic Cryaquept soil. Note the dark organic horizon over the saturated mineral horizon. This profile is described in Appendix B-5. Soil photo D.A. Walker no. 84-42-21; site photo D.A. Walker no. 84-42-18.

Figure 9. A Histic Pergelic Cryaquept soil. The major difference between this profile and the one in Figure 8 is the thicker organic horizon here. This profile is described in Appendix B-6. Soil photo D.A. Walker no. 84-42-9; site photo D.A. Walker no. 84-42-10.

VEGETATION

Vegetation Types

The vegetation classification resulted in 9 groups, 16 subgroups, and 23 community types (Table 7, Appendix C). These are arranged along a moisture gradient, from the driest areas in blockfields to the wettest sites, in ponds. Figure 10 illustrates the mosaic of vegetation types on the landscape and the relative cover of major types.

Group *Rhizocarpon geographicum - Cetraria nigricans* is found in blockfields and on glacial erratics (Figure 11). This lichen-dominated group contains a single subgroup and community type of the same name. It is floristically distinct from the other groups, and its characteristic taxa are all lichens. There are scattered vascular species within this type. This type has no soil.

Group *Dryas octopetala - Selaginella sibirica* occurs on soil of sandstone outcrops and till surfaces (Figure 12). This group is floristically diverse, and contains two subgroups and three community types. Community Type *Dryas octopetala - Carex obtusata* is a steppe-like type that includes graminoid and forb species not found elsewhere at Imnavait Creek, such as *Carex obtusata, Potentilla uniflora, Saxifraga tricuspidata*, and others, including the regional endemic *Erigeron muirii*. This type occurs only on non-hydric soils, primarily Pergelic Cryochrepts, with one occurrence of a Pergelic Cryorthent (Table 8).

Group *Arctous alpina - Hierochloë alpina* occurs at the shallow end of the snowbed vegetation gradient (Figure 13). It is characterized by the heath species *Arctous alpina, Vaccinium vitis-idaea*, and *V. uliginosum* and is relatively simple floristically, with only one subgroup and two community types. This type is common on till areas with shallow winter snow cover. The group occurs in small patches complexed with other vegetation types. Gentle surface undulations result in differences in winter snow accumulation that are reflected in the vegetation. This is a dry type; soils are non-hydric, primarily Pergelic Cryochrepts, with one occurrence of a Pergelic Cryorthent.

Group *Cassiope tetragona - Diapensia lapponica* is a complex group containing four subgroups and six community types that represents the main snowbed vegetation complex (Figure 14). Community types within this group share a high diversity and cover of fruticose lichen species and a set of characteristic species with high fidelity. Community type *Juncus biglumis - Luzula arctica* is a frost scar type; it has few species in common with the rest of the group. The three frost scar samples are not adequate to fully characterize the range of vegetation present on frost scars, which can range from wet to dry types. The group as a whole contains both hydric and non-hydric soil types: Pergelic Cryochrepts, Pergelic Cryorthents, and Pergelic Cryaquepts. Samples within this group were equally divided between hydric and non-hydric soils, but community types within the group are confined to one or two soil types.

Group *Eriophorum vaginatum - Sphagnum rubellum* is a complex of hillslope vegetation that encompasses the main tussock tundra types (Figure 15). It contains three subgroups and four community types, which differ from one another primarily in the relative dominance of various species rather than diagnostic species. This group occurs on hillslopes and in slightly elevated microsites (on palsas, or ice-cored mounds) in colluvial basins. Soils are all hydric and include

Table 7. Summary of the vegetation community classification at Imnavait Creek.

Group	Subgroup	Community type	Typical microsite	Plots
1. *Rhizocarpon geographicum - Cetraria nigricans* (RHIGEO - CETNIG)	1a. *Rhizocarpon geographicum - Cetraria nigricans* (RHIGEO - CETNIG)	*Rhizocarpon geographicum - Cetraria nigricans* (RHIGEO - CETNIG)	Xeric to subxeric, blockfields, glacial erratics	63, 64
2. *Dryas octopetala - Selaginella sibirica* (DRYOCT - SELSIB)	2a. *Dryas octopetala - Oxytropis nigrescens* (DRYOCT - OXYNIG)	*Dryas octopetala - Selaginella sibirica* (DRYOCT - SELSIB)	Xeric, extreme, wind-blown south-facing slopes and ridge crests on sandstone and shale outcrops	54, 58A
		Dryas octopetala - Carex obtusata (DRYOCT - CAROBT)	Xeric, wind-blown south-facing slopes on sandstone and shale outcrops	52, 53
	2b. *Dryas octopetala - Vaccinium vitis-idaea* (DRYOCT - VACVIT)	*Dryas octopetala - Vaccinium vitis-idaea* (DRYOCT - VACVIT)	Xeric, wind-blown glacial till and outwash deposits	33, 42
3. *Arctous alpina - Hierochloë alpina* (ARCALP - HIEALP)	3a. *Arctous alpina - Hierochloë alpina* (ARCALP - HIEALP)	*Vaccinium uliginosum - Arctous alpina* (VACULI - ARCALP)	Xeric to subxeric, shallow, south-facing snowbeds	51, 60
		Arctous alpina - Hierochloë alpina (ARCALP - HIEALP)	Subxeric, glacial till with shallow snow cover	9, 28, 38
4. *Cassiope tetragona - Diapensia lapponica* (CASTET - DIALAP)	4a. *Cassiope tetragona - Calamagrostis inexpansa* (CASTET - CALINE)	*Calamagrostis inexpansa - Vaccinium vitis-idaea* (CALINE - VACVIT)	Subxeric to mesic, snow-filled depressions on glacial till	39, 43
		Cassiope tetragona - Calamagrostis inexpansa (CASTET - CALINE)	Subxeric to mesic, stone stripes	29A, 30A, 32A, 44A

(Continued)

Table 7. (Continued)

Group	Subgroup	Community type	Typical microsite	Plots
	4b. *Cassiope tetragona - Carex microchaeta* (CASTET - CARMIC)	*Cassiope tetragona - Carex microchaeta* (CASTET - CARMIC)	Subxeric to mesic, moderately deep snowbeds, particularly on north-facing slopes	40, 41, 55, 56, 57
		Cassiope tetragona - Dryas integrifolia (CASTET - DRYINT)	Subxeric to mesic, minerotrophic snowbeds	26, 59
	4c. *Salix rotundifolia - Saxifraga nivalis* (SALROT - SAXNIV)	*Salix rotundifolia - Saxifraga nivalis* (SALROT - SAXNIV)	Mesic to subhygric, deep snowbeds	72, 73
	4d. *Juncus biglumis - Luzula arctica* (JUNBIG - LUZARC)	*Juncus biglumis - Luzula arctica* (JUNBIG - LUZARC)	Subxeric to subhygric, frost scars	69, 70, 71
5. *Eriophorum vaginatum - Sphagnum rubellum* (ERIVAG - SPHRUB)	5a. *Eriophorum vaginatum - Sphagnum rubellum* (ERIVAG - SPHRUB)	*Eriophorum vaginatum - Sphagnum rubellum* (ERIVAG - SPHRUB)	Mesic to subhygric, stable, sites on flat or gentle slopes	3, 4A, 50, 61, 62
		Carex bigelowii - Sphagnum rubellum (CARBIG - SPHRUB)	Subhygric, sites on steeper slopes with some solifluction	1, 6, 9, 12, 27, 31, 45
	5b. *Salix planifolia - Sphagnum rubellum* (SALPLA - SPHRUB)	*Salix planifolia - Sphagnum rubellum* (SALPLA - SPHRUB)	Subhygric to hygric, lower hillslopes	7, 35A
	5c. *Betula nana - Sphagnum rubellum* (BETNAN - SPHRUB)	*Betula nana - Cladina rangiferina* (BETNAN - CLARAN)	Mesic to subhygric, palsas	24, 67
		Betula nana - Rubus chamaemorus (BETNAN - RUBCHA)	Mesic to subhygric, palsas, high-centered polygons, margins of water tracks, slopes	5, 10, 13, 15, 17, 46, 48

(Continued)

Table 7. (Concluded)

Group	Subgroup	Community type	Typical microsite	Plots
6. *Eriophorum angustifolium - Valeriana capitata* (ERIANG - VALCAP)	6a. *Salix planifolia - Eriophorum angustifolium* (SALPLA - ERIANG)	*Salix planifolia - Eriophorum angustifolium* (SALPLA - ERIANG)	Subhygric to hygric, water tracks, wet hillslopes	2, 11, 34, 36A, 49
	6b. *Carex aquatilis - Salix chamissonis* (CARAQU - SALCHA)	*Carex aquatilis - Salix chamissonis* (CARAQU - SALCHA)	Subhygric, stream margins with deep winter snow	18, 47
7. *Salix fuscescens - Carex rariflora* (SALFUS - CARRAR)	7a. *Salix fuscescens - Carex rariflora* (SALFUS - CARRAR)	*Salix fuscescens - Sphagnum lenense* (SALFUS - SPHLEN)	Subhygric to hygric, hummocks, strangs, raised microsites in colluvial basins	14, 19, 20, 22B, 25A
		Carex rotundifolia - Sphagnum lindbergii (CARROT - SPHLIN)	Subhydric to hydric, wet meadows, poor fens in colluvial basins	21A, 22A, 25B
8. *Carex aquatilis - Eriophorum angustifolium* (CARAQU - ERIANG)	8a. *Carex aquatilis - Eriophorum angustifolium* (CARAQU - ERIANG)	*Carex aquatilis - Eriophorum angustifolium* (CARAQU - ERIANG)	Hydric, stream channels	16, 23
9. *Sparganium hyperboreum - Hippuris vulgaris* (SPAHYP - HIPVUL)	9a. *Sparganium hyperboreum - Hippuris vulgaris* (SPAHYP - HIPVUL)	*Sparganium hyperboreum - Hippuris vulgaris* (SPAHYP - HIPVUL)	Hydric, ponds	37, 65, 66

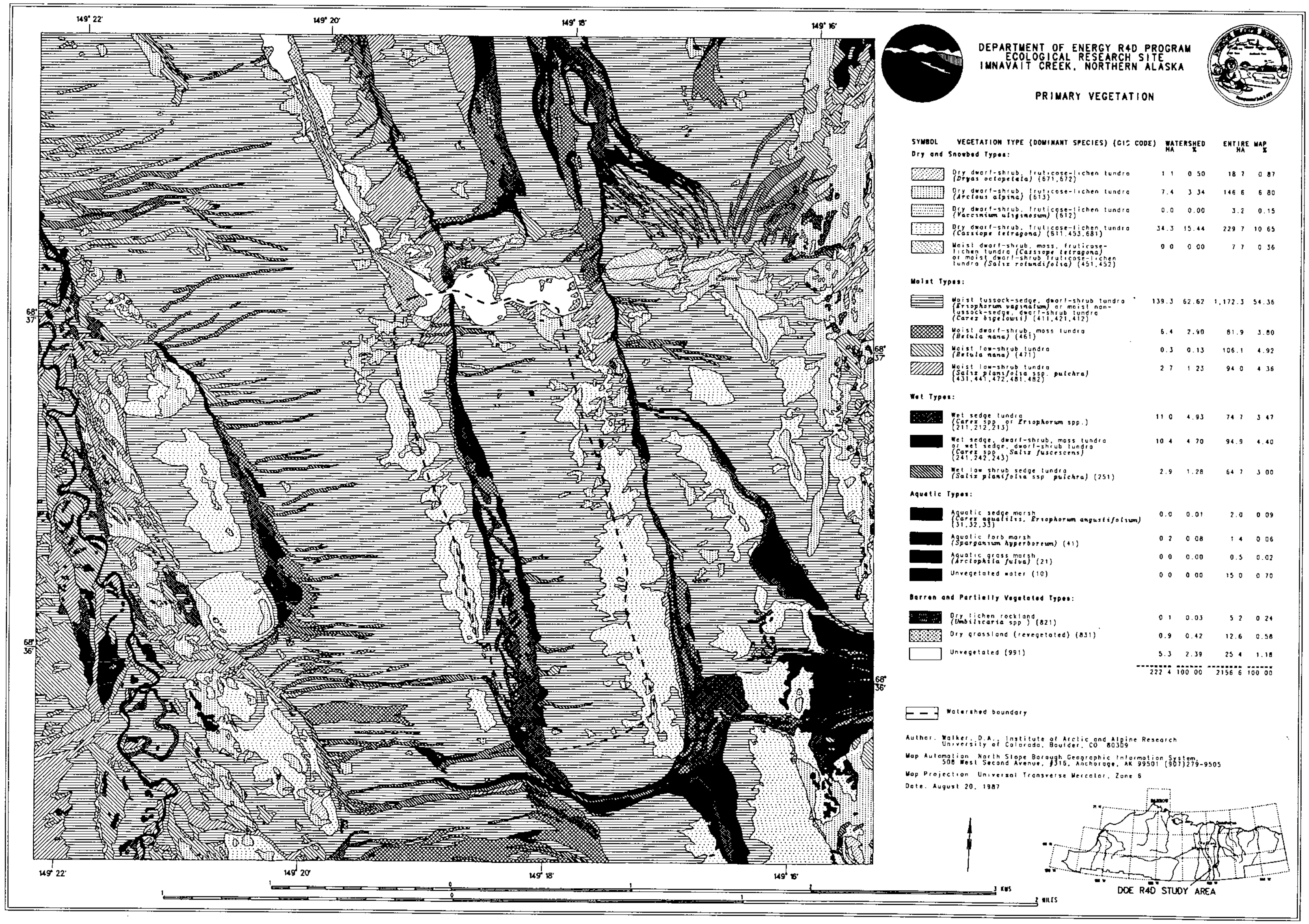


Figure 10. Vegetation of the Imnavait Creek area, from Walker et al. (1989).

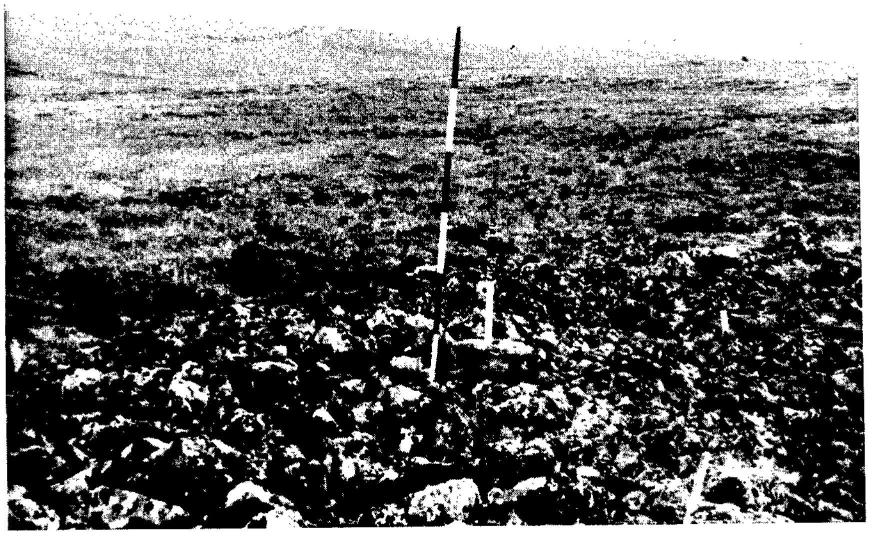


Figure 11. Vegetation group *Rhizocarpon geographicum - Cetraria nigricans.* Photo D.A. Walker no. 85-17-31.

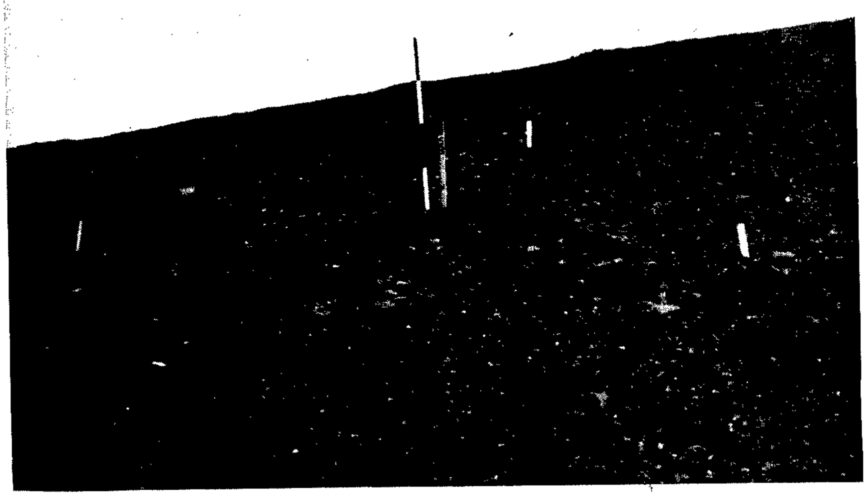


Figure 12. Community type *Dryas octopetala - Selaginella sibirica.* Photo D.A. Walker no. 85-16-29A.

Table 8. Distribution of soil types among vegetation groups and community types. Numbers represent count, column percent, and row percent.[a]

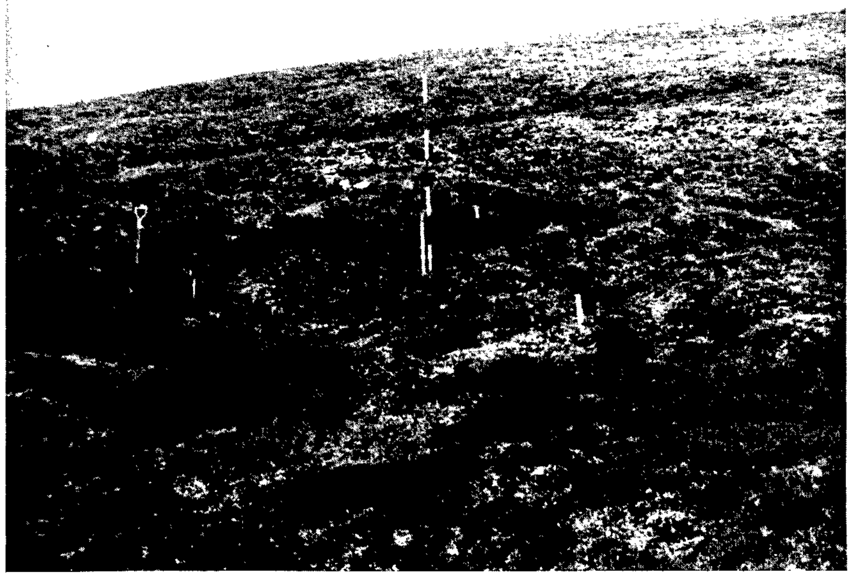
	Soil types						
Community types	Pergelic Cryochrept	Pergelic Cryorthent	Pergelic Cryaquept	Hist.Perg. Cryaquept	Hem. Perg. Sphagnofibrist	Pergelic Cryohemist	Pergelic Cryofibrist
Group DRYOCT-SELSIB							
DRYOCT-SELSIB	2/11.8/100.0						
DRYOCT-CAROBT	2/11.8/100.0						
DRYOCT-VACVIT	1/5.9/50.0	1/33.3/50.0					
Group ARCALP-HIEALP							
VACULI-ARCALP	2/11.8/100.0						
ARCALP-HIEALP	2/11.8/66.7	1/33.3/33.3					
Group CASTET-DIALAP							
CALINE-VACVIT	2/11.8/100.0						
CASTET-CALINE			4/19.0/100.0				
CASTET-CARMIC	4/23.5/80.0	1/33.3/20.0					
CASTET-DRYINT	1/5.9/50.0		1/4.8/50.0				
SALROT-SAXNIV	1/5.9/50.0		1/4.8/50.0				
JUNBIG-LUZARC			3/14.3/100.0				
Group ERIVAG-SPHRUB							
ERIVAG-SPHRUB			1/4.8/25.0	3/17.6/75.0			
CARBIG-SPHRUB			4/19.0/57.1	3/17.6/42.9			
SALPLA-SPHRUB			1/4.8/50.0	1/5.9/50.0			
BETNAN-CLARAN					2/66.7/100.0		
BETNAN-RUBCHA			2/9.5/33.3	3/17.6/50.0		1/20.0/16.7	
Group ERIANG-VALCAP							
SALPLA-ERIANG			3/14.3/50.0	2/11.8/33.3		1/20.0/16.7	
CARAQU-SALCHA			1/4.8/50.0	1/5.9/50.0			

(Continued)

Table 8. (Concluded)

Community types	Soil types						
	Pergelic Cryochrept	Pergelic Cryorthent	Pergelic Cryaquept	Hist.Perg. Cryaquept	Hem. Perg. Sphagnofibrist	Pergelic Cryohemist	Pergelic Cryofibrist
Group SALFUS-CARRAR							
SALFUS-SPHLEN				3/17.6/60.0	1/33.3/20.0	1/20.0/20.0	
CARROT-SPHLIN				1/5.9/33.3		2/40.0/66.7	
Group CARAQU-ERIANG							
CARAQU-ERIANG							2/40.0/100.0
Group SPAHYP-HIPVUL							
SPAHYP-HIPVUL							3/60.0/100.0

[a] Group *Rhizocarpon geographicum - Cetraria nigricans* is a blockfield type and has no soil.



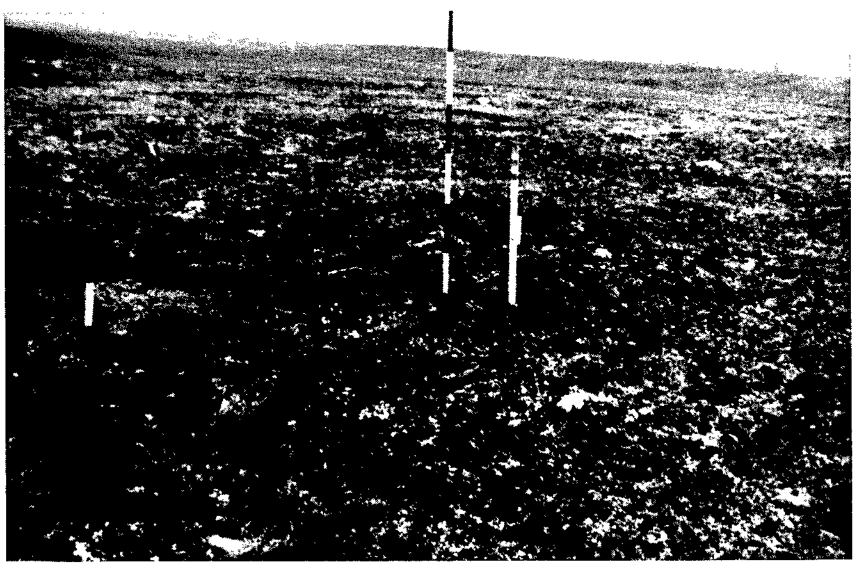


Figure 13. Community types *Vaccinium uliginosum* and *Arctous alpina* (top) and *Arctous alpina - Hierochloë alpina* (bottom), both in group *Arctous alpina - Hierochloë alpina.* Photos D.A. Walker no. 85-16-23A and 84-47-23.

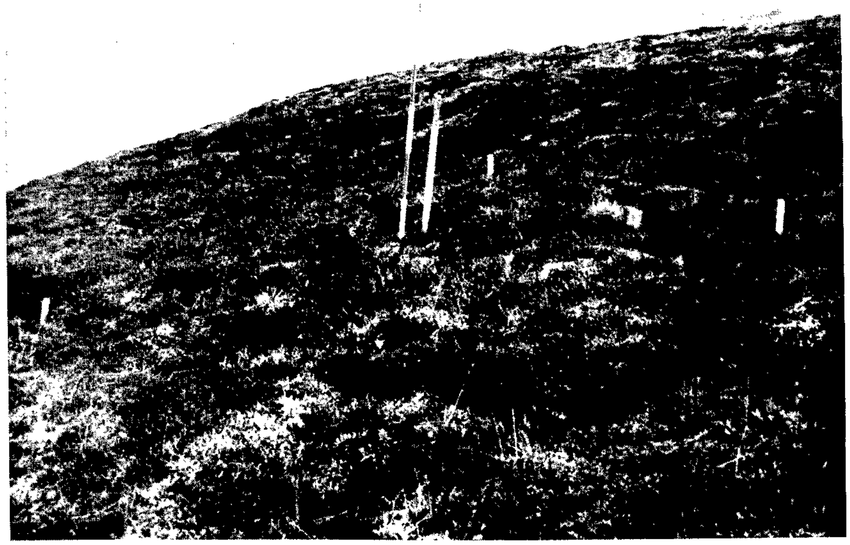


Figure 14. Stone-stripe complex with community type *Cassiope tetragona - Calamagrostis inexpansa* in dry stripe areas and community type *Carex bigelowii - Sphagnum rubellum* in peaty inter-stripe areas (top); north-facing slope with community type *Cassiope tetragona - Carex microchaeta* (bottom). Photos D.A. Walker no. 84-44-30 and 85-17-1.

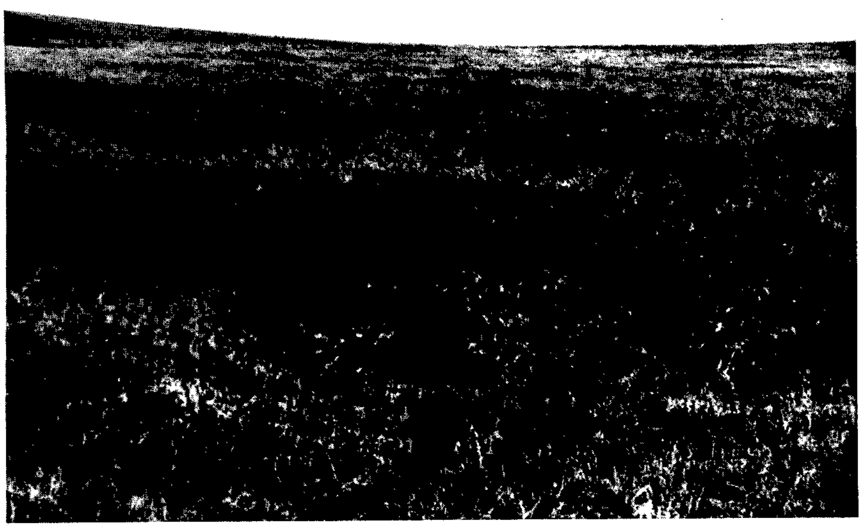


Figure 15. Community types *Eriophorum vaginatum - Sphagnum rubellum* (top) and *Betula nana - Rubus chamaemorus* (bottom) in group *Eriophorum vaginatum - Sphagnum rubellum*. The hummocky features in the top photograph are tussocks of *E. vaginatum*. Photos D.A. Walker nos. 84-41-31A and 84-44-17.

Pergelic Cryaquepts, Histic Pergelic Cryaquepts, Hemic Pergelic Sphagnofibrists, and one Pergelic Cryohemist.

Group *Eriophorum angustifolium - Valeriana capitata* is found within the hillslope water tracks and along the edges of streams (Figure 16). This group contains two subgroups with a single community type each that are well-differentiated from one another floristically. Soils are Pergelic Cryaquepts, Histic Pergelic Cryaquepts, and Pergelic Cryohemists.

Figure 16. Community type *Salix planifolia - Eriophorum angustifolium*. The two dominant species are clearly visible in the photograph. Photo D.A. Walker no. 84-41-24.

Group *Salix fuscescens - Carex rariflora* is a bog group that occurs primarily within colluvial basins (Figure 17). This group contains a single subtype and two community types. These sites are all characterized by an abundance of *Sphagnum* mosses, and the community types are differentiated based on the species of Sphagnum present within each. Soils are Histic Pergelic Cryaquepts, Pergelic Cryohemists, and one Hemic Pergelic Sphagnofibrist.

Group *Carex aquatilis - Eriophorum angustifolium* is an aquatic or semi-aquatic type that occurs in shallow pond areas, often between the ponds (beads) of Imnavait Creek (Figure 18). Soils are Pergelic Cryofibrists.

Group *Sparganium hyperboreum - Hippuris vulgaris* is an aquatic group that is limited to ponds of Imnavait Creek. Soils are Pergelic Cryofibrists.

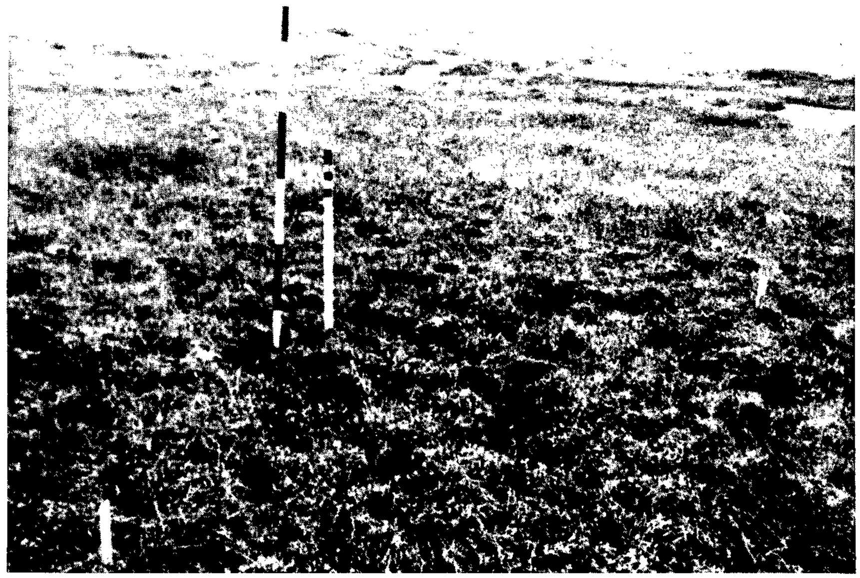


Figure 17. Community type *Salix fuscescens - Sphagnum lenense*. Photo D.A. Walker no. 84-43-28.

Figure 18. Beaded pond in Imnavait Creek. Community type *Carex aquatilis - Eriophorum angustifolium* is in the shallow areas between the ponds, and community type *Sparganium hyperboreum - Hippuris vulgaris* is in deep areas in the ponds. Photo D.A. Walker no. 85-18-4.

TOPOSEQUENCES

Vegetation

There are several distinct vegetation trends associated with the toposequence on west-facing slopes (Figure 19). (1) Overall species richness decreases down the slope; (2) graminoids are rare on the upper slopes, increase to a peak in the lower shoulder area (sample positions 4 and 16), and then gradually decrease downslope; (3) shrubs have a bimodal distribution. They are common on the ridge crests, represented at these sites primarily by dwarf ericaceous shrubs (e.g., *Vaccinium vitis-idaea, Arctous alpina, Diapensia lapponica*). They decrease in abundance in the shoulder area of the slopes, due to an abundance of graminoids. Shrub cover increases again in the lower backslope areas, where *Betula nana* and *Salix planifolia* ssp. *pulchra* become abundant, and then decrease again in the boggy lowermost slope areas; (4) bryophytes gradually increase in cover downslope; and (5) lichens decrease. The progression of soils is from non-hydric soils (Pergelic Cryochrepts) on the hill crest, into a transitional area on the shoulder and upper backslope with Pergelic Cryaquept soils, and finally into a wet area with Histic Pergelic Cryaquept soils (Figure 20). This increase in wetness downslope is also indicated by a decrease in the index average for vascular species (Figure 21).

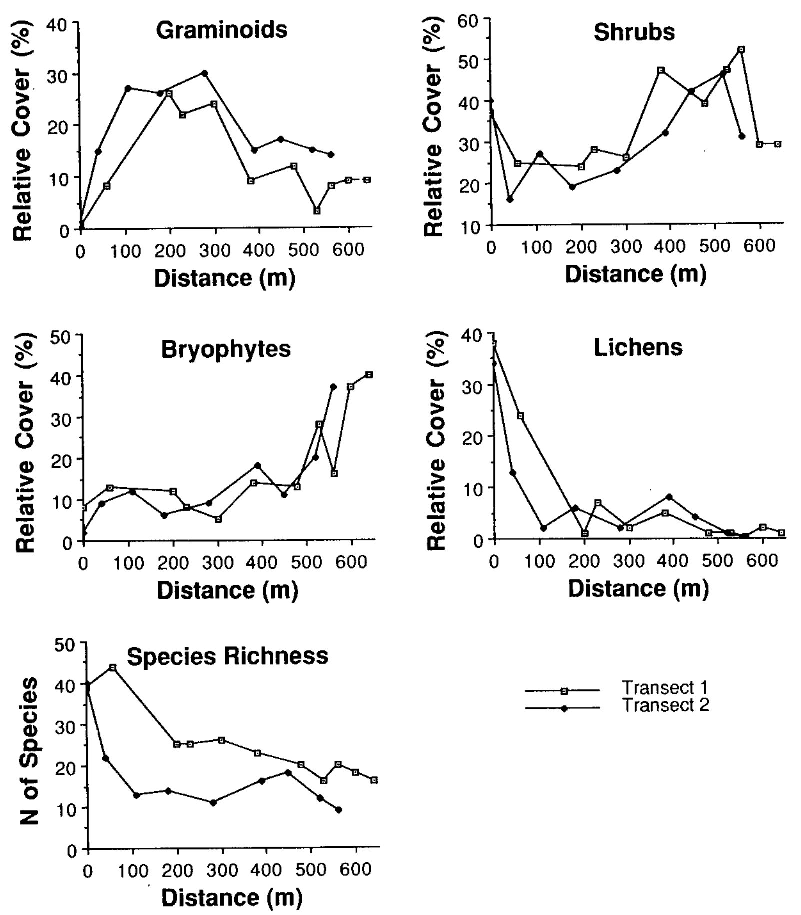


Figure 19. Changes in relative cover of major growth forms along the toposequence. Sample locations are shown in Figure 20. Data are from Walker and Lederer (1987).

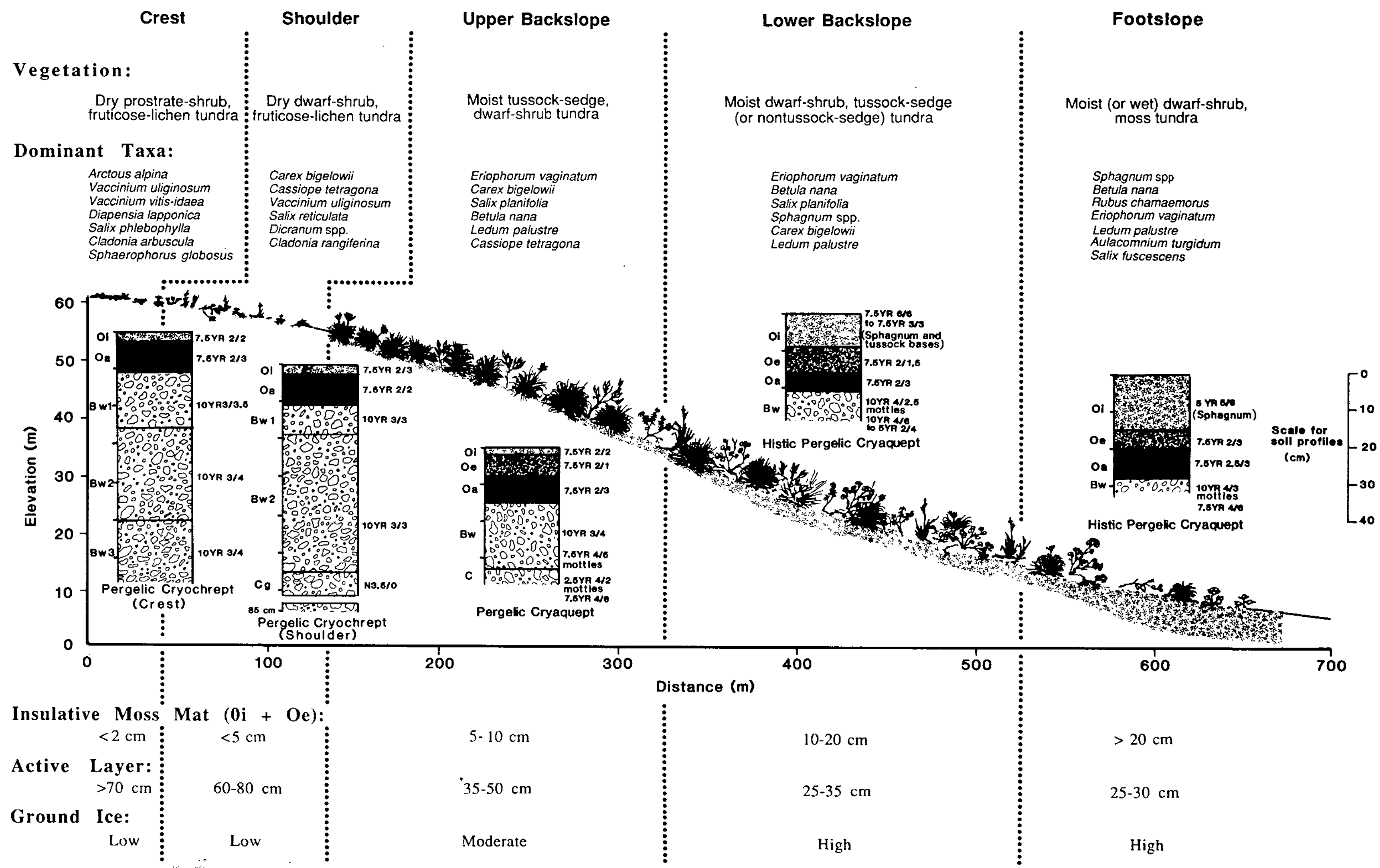


Figure 20. Idealized toposequence of an Imnavait Creek site hillslope (from Walker et al. 1989.)

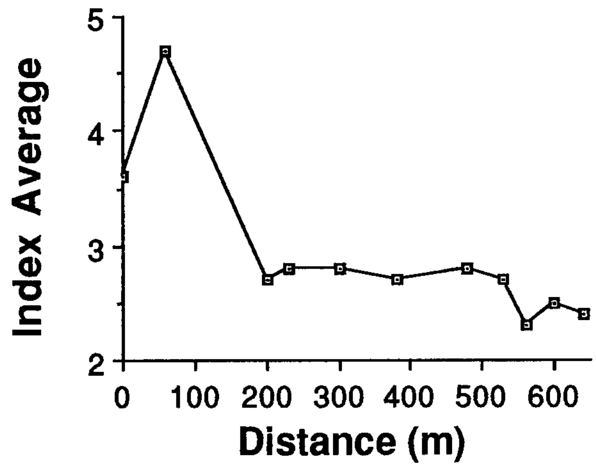


Figure 21. Vascular index average along toposequence transect no. 1. Sample locations are in Figure 20.

Soil Characteristics and Geochemistry

Physical characteristics of the soil also show distinctive trends associated with slope position. The organic component increases downslope, indicated by an increase in the depth of the organic horizons and an increase in the organic component of the mineral (Bw) horizon (Figure 22). Depth to permafrost is greatest in the lower shoulder position and then gradually decreases downslope. The vegetation and soil data indicate that the shoulder area is generally better drained than the slope crest, and has the highest species richness, the highest pH, the greatest cover of dwarf shrubs, and the deepest thaw. These areas have very little winter snow cover and thus dry out rapidly in the spring.

Soil pH for both extracts and soil solution gradually decreases downslope, although the very lowest pH values are in the Oa (sapric organic) horizon of the uppermost slope position (Figure 23). This is a typical pH sequence for mineral soils, caused by leaching of ions from the upper part of the hillslope (Birkeland 1984). The decrease downslope beyond this point is likely due to an increased abundance of *Sphagnum* moss and its acidifying effect. Solute pH is higher than soil pH due to dilution. Electrical conductivity of the soil solution shows an opposite though more complex pattern than pH. Conductivity increases downslope, probably due to increased concentrations of dissolved organic carbon. The trends in Figure 23 for the long lysimeters appear to correspond with the depth of the organic horizon in Figure 22, and the short lysimeter data correlate fairly well with the amount of organic material in the mineral (Bw) horizon. Because of the small number of samples, however, these trends could not be tested statistically.

Soil nutrients generally peak in the shoulder area and then decrease downslope (Figure 24). Potassium shows a very general trend toward decreasing amounts downslope, but there is considerable variation within this trend. Potassium is stored primarily in the upper organic horizons, with little in the Bw horizon. Soil sulfate in the Bw horizon shows a pattern much like the cations, a general downslope decrease. Soil nitrate is similar to the other nutrients, with a peak

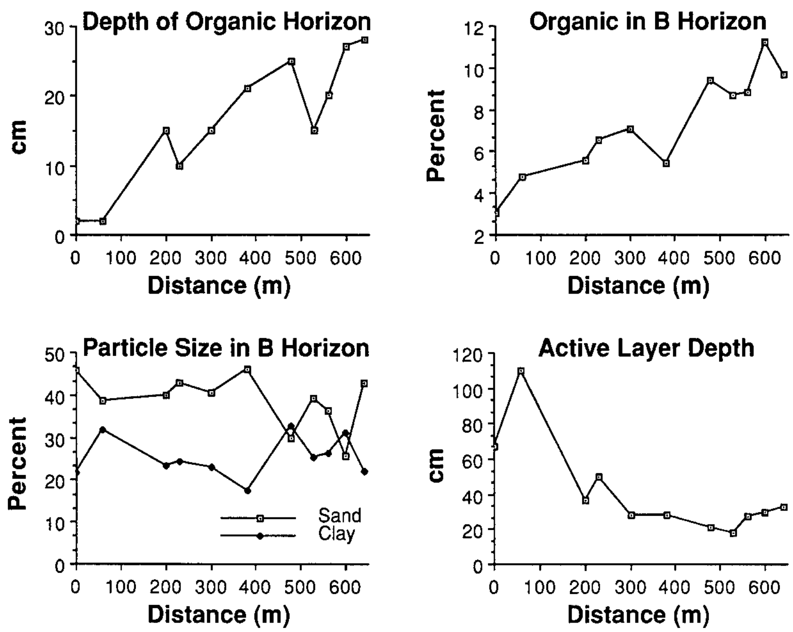


Figure 22. Soil physical characteristics along toposequence transect no. 1. Sample locations are in Figure 20.

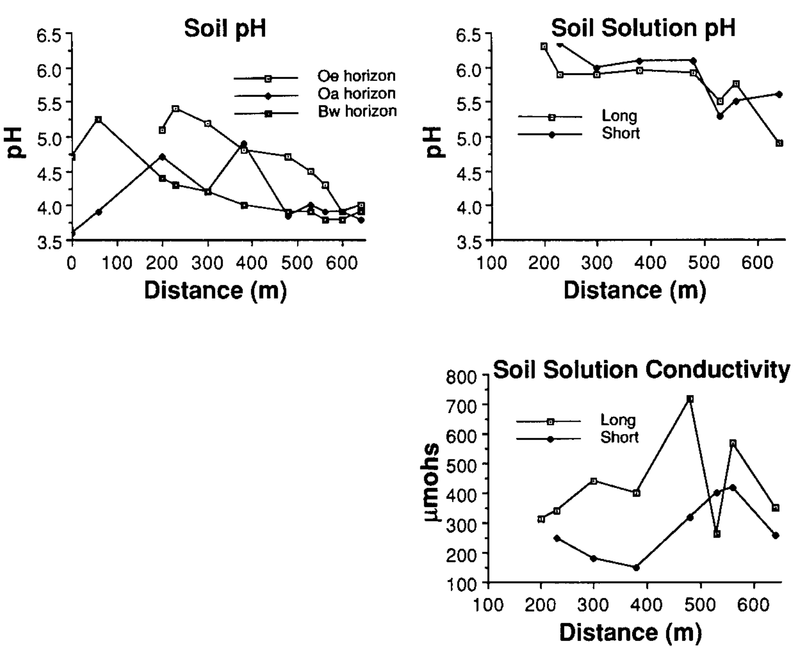


Figure 23. Soil and soil solution pH and electrical conductivity along toposequence transect no. 1. Sample locations are in Figure 20.

in the shoulder area, and soil phosphorus shows few recognizable trends. Soil solution data, which are more irregular downslope, are in Appendix D.

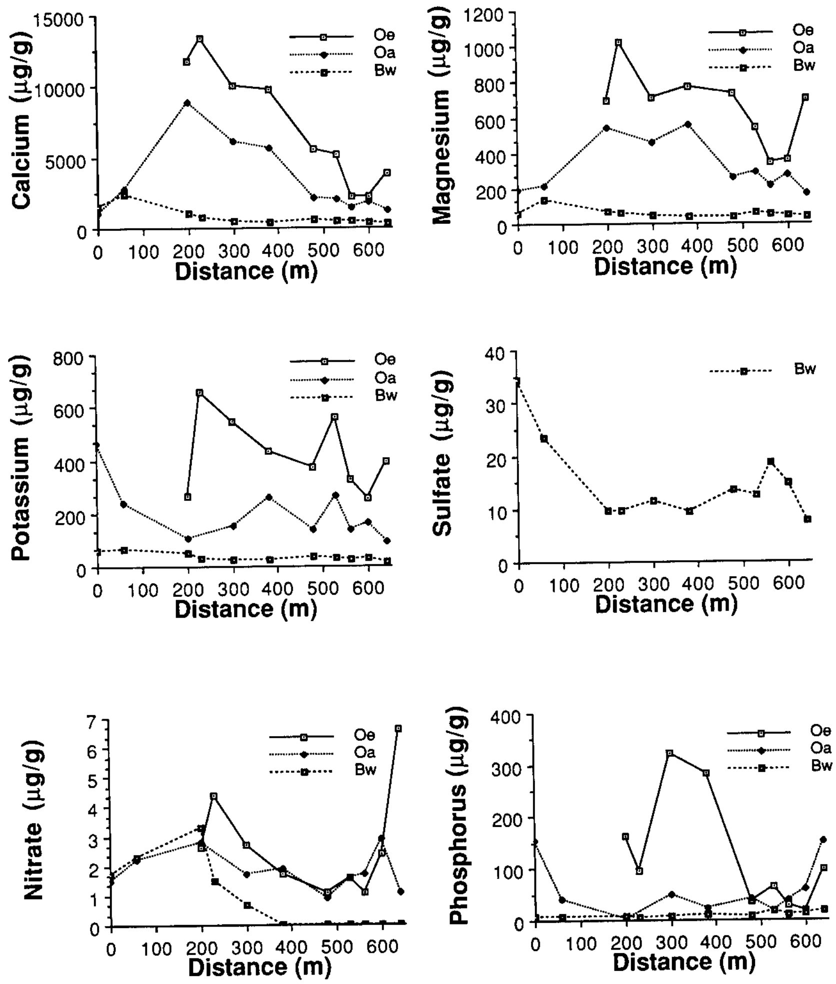


Figure 24. Nutrient concentrations in soil extracts along toposequence transect no. 1. Sample locations are in Figure 20.

VEGETATION-SOIL CORRELATIONS

Analysis by Soil Type

Vascular species. Both the weighted and index averages of the vascular species separate hydric and non-hydric soils into statistical subunits (Table 9). The non-hydric Pergelic Cryorthents and Pergelic Cryochrepts have both weighted and index averages greater than 3.0, and all other soils have mean averages less than 3.0. Differences between weighted and index averages are minor, but the index averages, which do not take into account the relative abundances of the species, produced a slightly better separation of the soil types. If the range of 2.5 to 3.5 is considered questionable for classification as a hydric soil based solely on these indices (Wentworth and Johnson 1986), then both the Pergelic Cryaquepts and Histic Pergelic Cryaquepts, with mean

index averages of 2.9 and 2.5 respectively, appear to require further study. The index averages for individual samples within the Pergelic Cryaquepts are highly variable, ranging from 1.1 to 4.4 (Figure 25). As already noted, Pergelic Cryaquepts are the most spatially extensive soil type, the most variable with respect to vegetation, and the most difficult for accurate determination of field moisture status.

Table 9. Weighted and index averages of vascular species by soil type. Differences among means are highly significant (F=19.434, $p < .0001$ for weighted averages; F=26.470, $p < .0001$ for index averages). Homogeneous subsets according to Duncan's multiple range test are shown with upper case letters; soil types with the same letter belong to a common subset. Means of soil types in different subsets are significantly different at the 95% level of confidence in both cases.

Soil type	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
Weighted averages:						
Pergelic Cryofibrist	A	1.0	0	1.0	1.0	3
Pergelic Cryohemist	A B	1.9	.23	1.3	2.4	5
Hemic Pergelic Sphagnofibrist	B C	2.2	.15	2.0	2.5	3
Histic Pergelic Cryaquept	B C	2.3	.13	1.1	3.1	20
Pergelic Cryaquept	C	2.9	.13	1.1	4.4	28
Pergelic Cryorthent	D	3.8	.34	3.2	4.6	4
Pergelic Cryochrept	D	3.8	.16	3.0	4.8	16
Index averages:						
Pergelic Cryofibrist	A	1.1	.10	1.0	1.3	3
Pergelic Cryohemist	B	1.9	.17	1.5	2.5	5
Hemic Pergelic Sphagnofibrist	B C	2.4	.17	2.1	2.7	3
Histic Pergelic Cryaquept	C	2.5	.09	1.5	2.9	20
Pergelic Cryaquept	C	2.9	.10	1.5	4.2	28
Pergelic Cryorthent	D	3.6	.24	3.2	4.3	4
Pergelic Cryochrept	D	3.8	.12	3.2	4.6	16

Cryptogam species. The bryophytes produce lower weighted and index averages than do the vascular species (Table 10), and the lichens produce higher values for both averages (Table 11). Whereas the range of mean weighted averages based on vascular species is 1.0 to 3.8, it is only 1.0 to 3.3 for bryophytes and 3.1 to 3.8 for the lichens. Index averages based on bryophytes statistically separate hydric and non-hydric soils, but when the weighted average is used, Pergelic Cryorthents are not differentiated from Hemic Pergelic Sphagnofibrists and Pergelic Cryaquepts. The range of individual samples is also a problem for both bryophyte averages, with non-hydric soils having ranges of values below 3.0 (both Pergelic Cryorthents and Pergelic Cryochrepts). All averages based on lichen species do not statistically separate hydric and non-hydric soils.

All canopy components combined. Although neither the bryophyte nor lichen components alone could accurately differentiate hydric and non-hydric soils, indices based on all three canopy components were calculated with the thought that the cryptogamic species might "fine tune" the indices. The non-hydric soils (Pergelic Cryochrepts and Pergelic Cryorthents) again had both weighted and index averages greater than 3.0, and the remaining soils had both averages less than

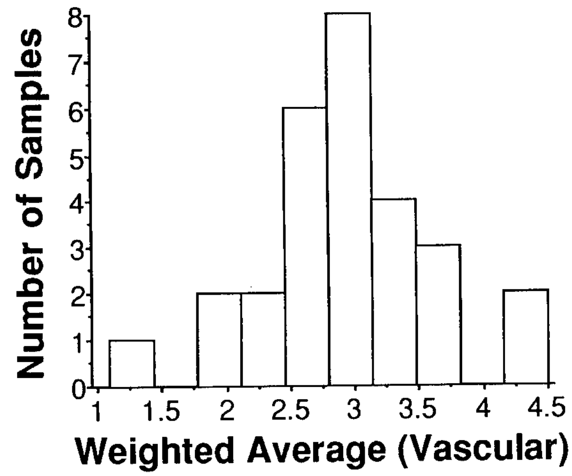


Figure 25. Frequency distribution of vascular weighted averages for Pergelic Cryaquept soil.

3.0 (Table 12). This is essentially the same result produced by both averages based on vascular species alone. The most likely reason for this similarity is that the lichens tend to increase the values and the bryophytes to decrease them. Thus, the two cancel one another out. Although there are more vascular species (110) than either of the other two categories, the total number of cryptogams (153) outweighs the vascular species. The small sample sizes for the organic soil types undoubtedly contribute to the minor variations in their position for the different analyses. For both the vascular species only and all canopy components combined, however, the Histosols always had weighted and index averages below 3.0.

Analysis by Vegetation Type

Calculation of weighted and index averages by vegetation group indicates that the units are well differentiated with regard to the presence or absence of wetland plant species (Table 13). If a mean of 3.0 is used as a cutoff for wetland types, then Group *Eriophorum vaginatum - Sphagnum rubellum* is a wetland. Group *Cassiope tetragona - Diapensia lapponica*, however, is neither clearly a wetland nor an upland type. Although it has a mean index average of 3.2, it has some very wet members, with values as low as 1.1. Evaluation by community type leads to a less ambiguous classification of types as wetlands or uplands (Table 14). Using either the index average for vascular species only, or the index or weighted averages for all species, the vegetation is separated into two distinct groups, and the break point is the same in all cases. The vascular weighted average results in a relatively unambiguous break point, with only community types *Carex bigelowii - Sphagnum rubellum* and *Cassiope tetragona* straddling wetland and non-wetland types. Overall, however, the separation is good, and the value of 3.0 is apparently adequate as the breaking point between the wetland and non-wetland vegetation.

Test of Indicator Status

A total of 28 species (25% of the total list) had species index averages that differed from the value listed in Reed (1988) by at least 1.0 (Table 15). This difference indicates that at Imnavait

Table 10. Weighted and index averages of bryophyte species by soil type. Differences among means are highly significant (F=20.955, $p < .0001$ for weighted averages; F=29.050, $p < .0001$ for index averages). Homogeneous subsets according to Duncan's multiple range test are shown with upper case letters; soil types with the same letter belong to a common subset. Means of soil types in different subsets are significantly different at the 95% level of confidence in both cases.

Soil type	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
Weighted averages:						
Pergelic Cryofibrist	A	1.0	.03	1.0	1.1	3
Pergelic Cryohemist	A B	1.6	.14	1.1	1.9	5
Histic Pergelic Cryaquept	B	1.9	.05	1.1	2.2	20
Hemic Pergelic Sphagnofibrist	B C	2.1	.15	1.8	2.3	3
Pergelic Cryaquept	C	2.3	.10	1.6	3.2	23
Pergelic Cryorthent	C D	3.0	.32	2.5	3.9	4
Pergelic Cryochrept	D	3.3	.18	2.2	4.5	16
Index averages:						
Pergelic Cryofibrist	A	1.2	.18	1.0	1.5	3
Pergelic Cryohemist	A B	1.7	.10	1.4	2.0	5
Hemic Pergelic Sphagnofibrist	B	2.0	.18	1.7	2.3	3
Histic Pergelic Cryaquept	B C	2.0	.06	1.3	2.3	20
Pergelic Cryaquept	C	2.3	.08	1.8	3.0	23
Pergelic Cryorthent	D	3.4	.19	3.0	3.9	4
Pergelic Cryochrept	D	3.4	.16	2.5	4.5	16

Creek these species are occurring most frequently with other species that do not share their wetland indicator status. This by no means indicates that the species is necessarily misclassified in Reed (1988), because it reflects only the species' distribution at Imnavait Creek. The categories in Reed (1988) are for all Alaska, and to be included in the Reed list a species must occur at least occasionally in wetlands; this is the major criterion used for inclusion on the list. With these precautions in mind, this list can be used to identify potential problems that might otherwise be missed.

Certain species stand out as being in particular need of review. *Campanula lasiocarpa* and *Loiseleuria procumbens* are not listed in Reed (1988), but their distribution at Imnavait Creek suggests that they do occur at least occasionally in wetlands. These species are listed in Appendix A as provisionally upland, but the analysis results suggest this is incorrect. Other species assigned a value of 5.0 (upland) due to their absence in Reed (1988) also differed by more than 1.0, but for the most part these are probably good upland species. *Carex aquatilis* is listed as an obligate wetland species, but it may occur in certain upland situations, and therefore it should be listed as facultative wetland rather than obligate. Other species listed as obligate wetland plants that should be reviewed include *Cardamine pratensis, Carex rariflora, Carex vaginata, Eriophorum triste, Juncus biglumis,* and *Saxifraga rivularis. Juncus biglumis* occurs frequently on moist frost scars and disturbances throughout the North Slope and is not limited to wetlands.

Eriophorum triste occurs outside wetlands in northern Alaska and should not be listed as obligate (Batten 1977; Komárková and Webber 1980; Ebersole 1985; Walker 1985, 1987). This

Table 11. Weighted and index averages of lichen species by soil type. Differences among means are highly significant (F=9.936, $p < .0001$ for weighted averages; F=10.828 for index averages). Homogeneous subsets according to Duncan's multiple range test are shown with upper case letters; soil types with the same letter belong to a common subset. Means of soil types in different subsets are significantly different at the 95% level of confidence.

Soil type[a]	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
Weighted averages:						
Pergelic Cryohemist	A	3.1	.1	3.0	3.3	3
Hemic Pergelic Sphagnofibrist	A	3.3	.03	3.2	3.3	3
Histic Pergelic Cryaquept	A B	3.3	.05	3.0	3.6	14
Pergelic Cryaquept	B C	3.5	.06	3.0	4.3	22
Pergelic Cryorthent	C	3.8	.15	3.5	4.1	4
Pergelic Cryochrept	C	3.8	.08	3.3	4.3	16
Index averages:						
Pergelic Cryohemist	A	3.1	.10	3.0	3.3	3
Hemic Pergelic Sphagnofibrist	A	3.1	.15	3.2	3.7	3
Histic Pergelic Cryaquept	A B	3.3	.05	3.0	3.6	14
Pergelic Cryaquept	B	3.5	.06	3.0	4.3	22
Pergelic Cryorthent	B	3.7	.08	3.6	3.9	4
Pergelic Cryochrept	B	3.8	.06	3.5	4.2	16

[a] There were no lichens in the Pergelic Cryofibrist soil type.

misclassification may be a result of confusion concerning subspecies. Hultén (1968) lists two subspecies of *Eriophorum angustifolium* in northern Alaska, *E. angustifolium* ssp. *subarcticum* and *E. angustifolium* ssp. *triste*. Reed (1988) lists *E. angustifolium* ssp. *subarcticum* as synonymous with *E. polystachion*, and lists this as an obligate wetland species, which is correct. Presumably, the species listed in Reed as *E. angustifolium* (no subspecies designated) is in fact *Eriophorum triste* (=*E. angustifolium* ssp. *triste*), since this species is not listed otherwise. The two forms of *Eriophorum angustifolium* are morphologically and ecologically distinct. These nomenclatural problems need to be clarified because these are both common species.

Kobresia myosuroides and *Trisetum spicatum* are both listed in Reed (1988) as facultative, indicating that between 33% and 67% of their occurrences are in wetlands, but these are both species primarily of dry ridge tops and alpine tundra (Böcher 1938; Hanson 1951; Spetzman 1959; Drew and Shanks 1965; Johnson 1966; Batten 1977; Walker 1985, 1987). They would be more accurately listed as upland species that rarely occur in wetlands. Their apparent occasional occurrence in wetlands is probably due to samples being placed in floristically and environmentally heterogeneous areas where hydric and non-hydric soils are in close spatial association.

CORRELATIONS WITH INDEPENDENT MEASURES OF WETNESS

Correlations of the wetland indices with independent wetness measures resulted in very high correlations between all index values and both site and soil moisture and moderate correlations

Table 12. Weighted and index averages of all canopy components combined by soil type. Differences among means are highly significant (F=22.296, p < .0001 for weighted averages; F=26.841 for index averages). Homogeneous subsets according to Duncan's multiple range test are shown with upper case letters; soil types with the same letter belong to a common subset. Means of soil types in different subsets are significantly different at the 95% level of confidence.

Soil type	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
Weighted averages:						
Pergelic Cryofibrist	A	1.0	.06	1.0	1.1	3
Pergelic Cryohemist	A B	1.7	.19	1.1	2.1	5
Histic Pergelic Cryaquept	B	2.2	.08	1.1	2.7	20
Hemic Pergelic Sphagnofibrist	B C	2.4	.24	1.9	2.7	3
Pergelic Cryaquept	C	2.8	.13	1.1	4.3	28
Pergelic Cryorthent	D	3.7	.25	3.1	4.3	4
Pergelic Cryochrept	D	3.8	.14	2.8	4.6	16
Index averages:						
Pergelic Cryofibrist	A	1.1	.26	1.0	1.3	3
Pergelic Cryohemist	B	1.9	.10	1.5	2.2	5
Histic Pergelic Cryaquept	B	2.3	.08	1.4	2.8	20
Hemic Pergelic Sphagnofibrist	B C	2.5	.26	2.1	3.0	3
Pergelic Cryaquept	C	2.9	.11	1.5	4.3	28
Pergelic Cryorthent	D	3.6	.14	3.4	4.0	4
Pergelic Cryochrept	D	3.7	.10	3.2	4.4	16

with end-of-season snow depth (Table 16). The correlations with moisture are expected; this basically supports the analysis of variance results. The correlations with snow cover indicate the overall importance of snow in controlling hydrology, soil type, and vegetation cover. These correlations are not particularly strong, however, indicating that snow acts in a complex manner that is not evident in a simple linear correlation.

DISCUSSION

USEFULNESS OF THE WETLAND INDEX METHOD IN NORTHERN ALASKA

The method of Wentworth and Johnson (1986) appears to be very useful for separation of hydric and non-hydric soil types in the acidic tussock tundra regions of northern Alaska. The small sample sizes for some soil and vegetation types indicate use of a certain degree of caution interpreting these results, but standard errors are mostly small, giving greater confidence in the reported values. Differences between weighted and index averages were minor and suggest that in the foothills simple lists of species may be adequate for proper characterization of soils. The similarity between the two types of averages is likely due to relatively even abundance of species within a sample, particularly after conversion to Daubenmire mid-point values. Vascular species produced results similar to those using vascular plus cryptogamic species.

Table 13. Weighted and index averages of vascular species by vegetation group. Differences among means are highly significant (F=41.916, $p < .0001$ for weighted averages; F=50.137 for index averages). Homogeneous subsets according to Duncan's multiple range test are shown with upper case letters; soil types with the same letter belong to a common subset. Means of groups in different subsets are significantly different at the 95% level of confidence.

Vegetation group	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
Weighted averages:						
SPAHYP-HIPVUL	A	1.0	0	1.0	1.0	3
CARAQU-ERIANG	A	1.0	0	1.0	1.0	2
SALFUS-CARRAR	A	1.6	.11	1.1	2.0	8
ERIANG-VALCAP	B	2.2	.10	1.8	2.6	7
ERIVAG-SPHRUB	C	2.6	.05	2.2	3.1	23
CASTET-DIALAP	D	3.3	.17	1.1	4.4	18
ARCALP-HIEALP	D	3.4	.15	3.1	3.9	5
RHIGEO-CETNIG	E	4.5	.50	4.0	5.0	2
DRYOCT-SELSIB	E	4.7	.08	4.3	4.8	6
Index averages:						
SPAHYP-HIPVUL	A	1.0	0	1.0	1.0	3
CARAQU-ERIANG	A	1.2	.15	1.0	1.3	2
SALFUS-CARRAR	B	1.9	.11	1.5	2.4	8
ERIANG-VALCAP	C	2.6	.06	2.3	2.8	7
ERIVAG-SPHRUB	C	2.6	.06	1.8	3.1	23
CASTET-DIALAP	D	3.2	.12	1.5	3.9	18
ARCALP-HIEALP	D	3.5	.11	3.2	3.8	5
DRYOCT-SELSIB	E	4.4	.11	3.9	4.6	6
RHIGEO-CETNIG	E	4.5	.50	4.0	5.0	2

Problems encountered with cryptogamic species are likely due at least in part to complex microtopography at the site. Cryptogams are distributed on a smaller spatial scale than are vascular plants, so that within an area of relatively homogeneous vascular plant cover there may be numerous microhabitats and resultant communities of cryptogams (Alpert and Oechel 1984). Thus, although a particular bryophyte species may have only a narrow range of moisture conditions that it can tolerate, within a single sample a species may be present due to microtopographic variation creating this particular condition in some portions of the sample. This effect can be seen in the very broad distributions of many cryptogamic species in Appendix C. Vascular species lists have undergone considerable review by experts and interagency panels, and although these lists undoubtedly have some problems they are mostly accurate. Because vascular species are much easier to identify in the field, and seem to adequately characterize the soils, at least at this site, there seems little need to collect information on cryptogams, at least when the sampling is all within acidic tundra areas.

A new technique that was introduced in this report was the calculation of species index averages from the calculated sample values. The resultant averages can be compared with the published lists as a quick and effective method of testing the accuracy of the lists. Although this

Table 14. Weighted and index averages of vascular species by community type. Differences among means are highly significant (F=35.282, $p < .0001$ for weighted averages; F=32.754 for index averages). Homogeneous subsets according to Duncan's multiple range test are shown with upper case letters; soil types with the same letter belong to a common subset. Means of groups in different subsets are significantly different at the 95% level of confidence.

Community type	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
Weighted averages:						
SPAHYP-HIPVUL	A	1.0	0	1.0	1.0	3
CARAQU-ERIANG	A	1.0	0	1.0	1.0	2
CARROT-SPHLIN	A	1.3	.09	1.1	1.4	3
SALFUS-SPHLEN	B	1.8	.07	1.6	2.0	5
CARAQU-SALCHA	B C	1.9	.10	1.8	2.0	2
JUNBIG-LUZARC	B C D	2.2	.57	1.1	3.0	3
SALPLA-ERIANG	B C D	2.3	.10	2.0	2.6	5
BETNAN-CLARAN	B C D E	2.4	.15	2.2	2.5	2
ERIVAG-SPHRUB	C D E	2.4	.04	2.3	2.5	5
SALPLA-SPHRUB	C D E	2.5	.10	2.4	2.6	2
BETNAN-RUBCHA	D E	2.7	.07	2.4	2.9	7
CARBIG-SPHRUB	E F	2.8	.06	2.6	3.1	7
CASTET-CALINE	F G	3.2	.16	2.8	3.5	4
CALINE-VACVIT	F G	3.2	.25	3.0	3.5	2
ARCALP-HIEALP	G	3.4	.25	3.1	3.9	3
VACULI-ARCALP	G	3.4	.20	3.2	3.6	2
CASTET-DRYINT	G	3.4	.25	3.2	3.7	2
CASTET-CARMIC	G	3.5	.13	3.3	4.0	5
SALROT-SAXNIV	H	4.3	.10	4.2	4.4	2
DRYOCT-VACVIT	H	4.4	.15	4.3	4.6	2
RHIGEO-CETNIG	H	4.5	.50	4.0	5.0	2
DRYOCT-CAROBT	H	4.8	.05	4.7	4.8	2
DRYOCT-SELSIB	H	4.8	0	4.8	4.8	2
Index averages:						
SPAHYP-HIPVUL	A	1.0	0	1.0	1.0	3
CARAQU-ERIANG	A B	1.2	.15	1.0	1.3	2
CARROT-SPHLIN	B	1.6	.07	1.5	1.7	3
SALFUS-SPHLEN	C	2.0	.11	1.8	2.4	5
JUNBIG-LUZARC	C D	2.3	.44	1.1	3.0	3
BETNAN-CLARAN	C D	2.4	.30	2.1	2.7	2
CARAQU-SALCHA	C D	2.4	.15	2.3	2.6	2
BETNAN-RUBCHA	D	2.7	.07	2.4	2.9	7
SALPLA-ERIANG	D	2.6	.06	2.5	2.8	5
SALPLA-SPHRUB	D	2.6	.15	2.5	2.8	2
ERIVAG-SPHRUB	D	2.7	.04	2.6	2.8	5
CARBIG-SPHRUB	D	2.8	.08	2.5	3.1	7
CASTET-CALINE	E	3.2	.07	3.0	3.3	4
CASTET-DRYINT	E	3.4	.15	3.2	3.5	2
ARCALP-HIEALP	E	3.4	.15	3.2	3.7	3
CALINE-VACVIT	E	3.2	.05	3.4	3.5	2

(Continued)

Table 14. Concluded

Community type	Homogeneous subsets	Mean	S.E.	Min.	Max.	n
CASTET-CARMIC	E	3.5	.12	3.2	3.9	5
SALROT-SAXNIV	E F	3.6	.10	3.5	3.7	2
VACULI-ARCALP	E F	3.7	.10	3.6	3.8	2
DRYOCT-VACVIT	F G	4.1	.20	3.9	4.3	2
RHIGEO-CETNIG	G	4.5	.50	4.0	5.0	2
DRYOCT-SELSIB	G	4.5	.10	4.4	4.6	2
DRYOCT-CAROBT	G	4.6	.05	4.5	4.6	2

type of averaging will cause some compression in the range of values, the effect is minor after only one iteration, and species with calculated index averages that consistently vary from their published indicator status are likely misclassified on the published list. Application of this method to other areas of Alaska is needed to confirm results presented here. Because of the wide range of climatic and habitat conditions in Alaska, subregional indicators might be more precise. Many of the species listed in Table 15 are probably actually classified correctly in Reed (1988), but others are obviously in error and were overlooked by reviewers. These problems were not noted by a simple visual check of the species lists.

PROBLEMS WITH HYDRIC SOIL AND WETLAND DETERMINATIONS IN NORTHERN ALASKA

Although wetlands are conceptually rather easy to define, the actual designation of field sites as either wetland or non-wetland (upland) is often difficult. As ecotonal areas, wetlands grade into surrounding uplands with no clear division between the two. The FWS defines wetlands broadly, and their definition is worded such that if any of the specified criteria are met, then the site qualifies as a wetland (Cowardin et al. 1979). These criteria are (1) the land predominantly supports hydrophytes, (2) the substrate is undrained hydric soil, or (3) the substrate is nonsoil and saturated or covered with water during the growing season. Most of Alaska has not been mapped and classified into soil series as has most of the land in the lower 48 States (Rieger et al. 1979). Other reports in this series have had hydric soils determined independently either from SCS lists or by having an SCS or U.S. Forest Service soil scientist define the soil as hydric prior to sampling (Dick Peddie et al. 1987; Eicher 1988). This lack of independent classification creates certain problems in interpretation of the results presented here. To understand this problem, a review of terms and conditions associated with hydric soils is helpful.

The SCS has issued a list of hydric soil series of the U.S. (SCS 1985), which states that "A hydric soil condition exists when the soil in its natural undrained state is saturated at or near the surface during much of the growing season." Taken by itself, this criterion would not be difficult to apply. However, it then states three major criteria that are used for determining hydric status: (1) an aquic moisture regime, (2) a deficiency of oxygen at or near the surface during the growing season, and (3) flooding or ponding of long duration during the growing season. Furthermore, it states that the ultimate test is whether or not the soil supports predominantly hydrophytes. Hydrophytes are defined by Cowardin et al. (1979) as "any plant growing in water or on a

Table 15. Species with a reciprocal average index value that varies from the value listed in Reed (1988) by at least 1.0. Values from Reed (1988) correspond to the wetland indicator classes: 1 - obligate wetland, 2 - facultative wetland, 3 - facultative, 4 - facultative upland, and 5 - upland.

Species	Reed (1988) value	Calculated value
*Arnica lessingii**	5	3.5
Artemisia arctica ssp *arctica**	5	3.7
Calamagrostis inexpansa	2	3.2
*Campanula lasiocarpa**	5	2.3
Cardamine pratensis	1	2.5
Carex aquatilis	1	2.0
*Carex obtusata**	5	3.9
Carex rariflora	1	2.0
Carex saxatilis	2	3.2
Carex vaginata	1	3.2
*Diapensia lapponica**	3	5.0
Equisetum variegatum	2	3.5
Eriophorum triste	1	2.9
*Hierochloë alpina**	5	3.8
Huperzia selago ssp. *appressa*	5	3.1
Juncus biglumis	1	2.6
Kobresia myosuroides	3	4.2
*Loiseleuria procumbens**	5	3.3
Luzula wahlenbergii	1	2.5
*Minuartia arctica**	5	3.8
*Oxytropis nigrescens**	5	3.2
Pedicularis langsdorfii	2	3.2
*Poa paucispicula**	5	3.6
*Salix chamissonis***	2	3.0
*Salix rotundifolia***	5	3.5
Saxifraga rivularis	1	3.5
*Silene acaulis**	5	3.5
Trisetum spicatum	3	4.5

[a] * - not listed in Reed (1988).
** - listed in Reed (1988) as insufficient data available to determine status.

substrate that is at least periodically deficient in oxygen as a result of excessive water content." Thus, the FWS defines wetlands based on the presence of hydrophytes and hydric soils, and hydric soils are defined by the SCS as supporting hydrophytes. Since the key factor in hydrophyte definition is a deficiency of oxygen, at least periodically, this factor stands out as the only truly independent test of hydric soil conditions.

In the northern Alaska foothills, which are for the most part gently rolling, soils are predominantly Pergelic Cryaquepts and Histic Pergelic Cryaquepts, both of which by definition have an aquic moisture regime, one criterion used by the SCS to determine wetland status. Since "[a]n aquic moisture regime must be a reducing one" (Soil Survey Staff 1975), the plant species supported by these soils would, by Cowardin et al.'s (1979) definition, be hydrophytes, and the

Table 16. Pearson product-moment correlations between weighted and index averages and environmental variables. Numbers are r^2, probability, and sample size.

Index type	Soil moisture	Site moisture	Snow depth (May 1986)
Vascular weighted	.747	.745	.073
	.0001	.0001	.0547
	69	84	51
Vascular index	.743	.744	.099
	.0001	.0001	.0244
	69	84	51
Bryophyte weighted	.685	.735	.146
	.0001	.0001	.0057
	68	79	51
Bryophyte index	.768	.789	.152
	.0001	.0001	.0046
	68	79	51
Lichen weighted	.637	.657	.157
	.0001	.0001	.0079
	55	64	44
Lichen index	.628	.695	.143
	.0001	.0001	.0113
	55	64	44
All components weighted	.824	.819	.116
	.0001	.0001	.0146
	69	84	51
All components index	.835	.834	.124
	.0001	.0001	.0112
	69	84	51

soils should therefore be considered hydric. On close inspection, however, these definitions become very difficult to apply consistently.

Evidence of a reducing state is generally a neutral gray or greenish color in the mineral horizons, often with reddish mottles indicating areas of sporadic oxidation. Saturation alone does not necessarily lead to a reducing environment; this occurs only when all of the dissolved oxygen has been reduced (Everett 1984). The period of saturation may be much longer than the period of reduction (Vepraskas and Wilding 1983). Many of the existing definitions that require a reducing environment would be far less ambiguous and easier to apply if they addressed saturation alone. Many foothills soils apparently never develop a negative Eh. In those that do, Eh's are positive during most of the growing season and become reducing once the surface freezes, at which time

the plants are dormant (Everett 1984; Chapin et al. 1988). This seasonal difference suggests that until freeze-up occurs diffusion of oxygen from air into the soil may be sufficient to maintain an oxidizing state. Yet these soils have traditionally been classified as having an aquic moisture regime based on the presence of mottles. Microtopographic differences of only 10 to 20 cm may result in soil complexes with both reducing and oxidizing conditions. Taking the definitions very literally, many foothills soils do not appear to have an aquic moisture regime if the reduction concept is rigorously applied.

This problem is largely semantic. If the letter of the definition requires only that the soil be saturated for at least a few days during the growing season, which has been presumed to result in reduction, then these soils meet the requirements, because their lower mineral horizons are saturated, often throughout the growing season. A more important question is, should all surfaces with hydric soils be classified as wetlands? Should concepts and definitions developed primarily for temperate regions be applied to soils with permafrost without modification? Pergelic Cryaquept soils at Imnavait Creek have weighted and index averages that range from nearly 1.0 to greater than 4.0. Because the soils in this study were described from the same sites as the vegetation samples, there is little or no chance for soil and vegetation to be mismatched, which can occur if vegetation sampling locations are determined from a soil map. Thus, the broad range of indices for Pergelic Cryaquepts likely represents a true range for this soil type. Wentworth and Johnson (1986) suggest that in cases where mean index values are between 2.5 and 3.5, further field studies may be required, particularly on soils and hydrology. In the Arctic Foothills, however, further research on soils and hydrology is not likely to yield any more definitive answers. What is perhaps most needed is a study of the functional ecological role that these soils play (Adamus and Stockwell 1982). Given the ambiguities that exist in trying to classify these soils as either hydric or not, decisions based on function rather than strict application of criteria would be more defensible.

Cowardin et al. (1979, plate 67) explicitly recognized tussock tundra as a wetland type. Their classification is: SYSTEM Palustrine, CLASS Emergent Wetland, SUBCLASS Persistent, DOMINANCE TYPE Eriophorum vaginatum, WATER REGIME Saturated, WATER CHEMISTRY Fresh, SOIL Mineral. This type occurs primarily on well-drained hillslopes, and these are not important habitat for animal species normally associated with wetlands, such as shorebirds and waterfowl. Geochemical data presented here and elsewhere suggest that lateral movement of water through the soil profile is minimal and probably only occurs during major rainfall events. The organic horizons, in which the plant species are rooted, may become quite dry in mid to late summer. Thus, these areas do not appear to function hydrologically as wetlands, either. It is quite possible that, definitions of hydric soils aside, some Pergelic Cryaquepts do support wetlands while others do not. The wide range of weighted and index averages for this soil type supports this conclusion.

One solution to this problem would be to define phases of the soil based on slope position, vegetation community type, or both. Examination of the index averages by community type (Table 14) and the correlation between soil and community types (Table 8) helps illustrate this concept and how it might work. Group *Cassiope tetragona - Diapensia lapponica* occurs on both hydric (Pergelic Cryaquept) and non-hydric (Pergelic Cryorthent and Pergelic Cryochrept) soil types. Four of the community types within this group occur at least some of the time on Pergelic Cryaquepts, and the rest are limited to non-hydric soil types. Of these four community types, *Juncus biglumis - Luzula arctica* is statistically grouped with other types having mean index values below 3.0, and *Cassiope tetragona - Calamagrostis inexpansa, Cassiope tetragona - Dryas integrifolia*, and *Salix rotundifolia - Saxifraga nivalis* are statistically grouped with types having mean index values above 3.0. All other community types within this group, which never occur on hydric soils, are grouped statistically with types having mean values above 3.0. A floristically

based classification, such as the one presented here, and subsequent designation of community types as either wetland or upland would be relatively easy to apply in the field and produce less ambiguous results than simply designating all Pergelic Cryaquept soils as hydric and therefore wetlands. The vegetation classification, however, must be based on floristics and not on structure, physiognomy, or growth forms, because it is at the species level that these differences are expressed. The Braun-Blanquet (1932) technique is a floristic system that has been used widely in the Arctic, including Alaska and Canada (Gjaerevoll 1954, 1968, 1980; Rønning 1965; Odasz 1983; Ebersole 1985; Elvebakk 1985; Gunnlaugsdottír 1985; Cooper 1986; Walker 1987), and would be an appropriate system for this type of classification.

REGIONAL APPLICATION OF RESULTS

The hydrologic and geochemical regimes in the Imnavait Creek watershed are similar to those reported from other foothills watersheds (Everett and Ostendorf 1988). The array and relative abundance of the soil and vegetation types are representative of the Southern Foothills Physiographic Province. There are, however, a number of spatially extensive foothills soil types, in the Mollisol order, that are not represented in this study. The primary factor separating Mollisols from Inceptisols is the base saturation of the upper horizons, or the epipedon. The Mollisols are defined by the presence of a mollic epipedon, which, among other things, must be at least 50% base saturated. Areas of the foothills and coastal plain that are downwind from major rivers carrying calcareous sediments from the Brooks Range, in particular the Sagavanirktok River, have continual deposition of calcium-rich loess from these rivers (Walker and Webber 1979; Walker 1985; Walker and Acevedo 1987). Effects of loess on soils and vegetation are complex, but some of the major differences include coarser soil textures, high pH, higher nutrient status, less organic content, and lower water-holding capacity. Plant species, particularly mosses, are highly sensitive to pH differences (Sjørs 1950, Jeglum 1971; Walker 1987; Walker and Everett 1987). Loess is a major factor affecting the distribution of soil and vegetation types on the coastal plain and in the foothills (Everett and Parkinson 1977; Everett 1980b; Walker and Everett unpublished manuscript).

Approximate soil type equivalents on alkaline tundra for the seven soils listed in this study are shown in Table 17. There are very few Histosols in regions with heavy loess fallout because of the relatively slow peat-forming character of non-Sphagnum mosses, and because continual deposition of mineral material often prevents the necessary percentage of soil organic material from accumulating. The dominant species are also quite different. *Eriophorum vaginatum, Betula nana*, and *Salix planifolia* ssp. *pulchra* are rare in alkaline tundra areas, where the more common species are *Salix glauca, Salix lanata*, and *Eriophorum triste*. Ericaceous shrub species, with the exception of *Cassiope tetragona*, are rare or absent in alkaline tundra. *Sphagnum* mosses, which are so important in controlling many soil and hydrologic processes, are extremely sensitive to high pH and are missing entirely in alkaline areas. These various species define the community types at Imnavait Creek. Because the vegetation types are different in alkaline tundra areas, the results presented here should not be extended to those areas.

Table 17. Approximate soil type equivalents in alkaline tundra for the seven soil types described at Imnavait Creek. When more than one type is listed, the first is the most likely of the two.

Soil type	Typical microsite	Equivalent alkaline type
Pergelic Cryofibrist	Ponds, aquatic tundra	Pergelic Cryofibrist
Hemic Pergelic Sphagnofibrist	Colluvial basins	Pergelic Cryofibrist [a]
Pergelic Cryohemist	Wet tundra	Pergelic Cryohemist <u>or</u> Pergelic Cryaquoll
Histic Pergelic Cryaquept	Hillslopes, lower positions	Pergelic Cryaquoll
Pergelic Cryaquept	Hillslopes, upper positions	Pergelic Cryaquoll
Pergelic Cryorthent	Erosional surfaces	Pergelic Cryorthent
Pergelic Cryochrept	Ridge crests and shoulder	Pergelic Cryaquoll <u>or</u> Pergelic Cryochrept

[a]It is unknown if colluvial basins occur in alkaline regions.

REFERENCES

Adamus, P.R., and L.T. Stockwell. 1982. A method for wetland functional assessment. Vol. 1: Critical review and evaluation concepts. U.S. Department of Transportation, Federal Highway Administration, Office of Research, Environmental Division, Washington, DC.

Alpert, P., and W.C. Oechel. 1984. Microdistribution and water loss resistances of selected bryophytes in an Alaskan *Eriophorum* tussock tundra. Holarct. Ecol. 7:111-118.

Anderson, J.C., and D.K. MacKay. 1974. Progress of hydrologic studies at Boot Creek and Peter Lake watersheds, N.W.T. during 1973. Pages 203-223 *in* Hydrological aspects of northern pipeline development, a series of 16 reports, Rep. no 74-12. Northern Pipeline Task Force on Northern Oil Development, Glaciology Division, Canada Water Resources Branch, Dept. of Environment, Ottawa.

Andrus, A.E. 1984. The *Sphagna* of New York State. Ph.D. Dissertation. University of New York, Syracuse. 421 pp.

Arctic Environmental Information and Data Center and University of Alaska. 1975. Alaska regional profiles, Arctic Region. Atlas sponsored by the State of Alaska in cooperation with the Joint Federal-State Land Use Planning Commission for Alaska.

Batten, A.R. 1977. The vascular floristics, major vegetation units, and phytogeography of the Lake Peters area, northeastern Alaska. M.S. Thesis. University of Alaska, Fairbanks. 330 pp.

Benson, C.S. 1982. Reassessment of winter precipitation on Alaska's Arctic Slope and measurements on the flux of wind blown snow. Page 26 *in* Geophysical Institute UAG R-288. Fairbanks, AK.

Birkeland, P.W. 1984. Soils and geomorphology. Oxford University Press, Oxford. 372 pp.

Black, R.F., and W.L. Barksdale. 1949. Oriented lakes of northern Alaska. J. Geol. 57:105-118.

Bliss, L.C., and J.E. Cantlon. 1957. Succession on river alluvium in northern Alaska. Am. Midl. Nat. 58:452-469.

Böcher, T.W. 1938. Biological distributional types in the flora of Greenland. Medd. Groenl. 106:1-339.

Boelter, D.H. 1965. Hydraulic conductivity of peats. Soil Sci. 100:227-231.

Boelter, D.H. 1970. Important physical properties of peat material. Pages 150-154 *in* Proc. Third Intl. Peat Congr., 1968. Quebec.

Boelter, D.H. 1972. The hydrological characteristics of undrained organic soils in the Lake states. *In* Proceedings of the Organic Soils Symposium, Soil Science Society of America, Miami Beach, FL, 29 October - 3 November 1972. Soil Science Society of America, Madison, WI.

Braun Blanquet, J. 1932. Plant sociology. McGraw-Hill, New York. 439 pp. [Translated by D.G. Fuller and H.S. Conard.]

Brosgé, W.P., H.N Reiser, J.T. Dutro, Jr., and R.L. Detterman. 1979. Bedrock geologic map of the Philip Smith Mountains Quadrangle, Alaska. U.S. Geological Survey Miscellaneous Field Studies Map MF-879 B, Scale 1:250,000, 2 sheets.

Brown, J., and R.L. Berg, eds. 1980. Environmental engineering and ecological baseline investigations along the Yukon River - Prudhoe Bay Haul Road. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 80-19. 187 pp.

Brown, J., S.L. Dingman, and R.I. Lewellen. 1968. Hydrology of a drainage basin on the Alaskan Coastal Plain. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 240. 18 pp.

Cantlon, J.E. 1961. Plant cover in relation to macro-, meso- and micro-relief. Final report, Office of Naval Research, Grants No. ONR-208 and 216. 128 pp.

Chapin, F.S. 1972. Phosphate uptake by *Eriophorum vaginatum*. Pages 46-50 *in* Proc. 1972 Tundra Biome Symp., Lake Wilderness Center, University of Washington, Seattle.

Chapin, F.S., III, and A. Bloom. 1976. Phosphate absorption: adaptation of tundra graminoids to a low temperature, low phosphorus environment. Oikos 26:111-121.

Chapin, F.S., III, N. Fetcher, K. Kielland, K.R. Everett, and A.E. Linkins. 1988. Productivity and nutrient cycling of Alaskan tundra: enhancement by flowing soil water. Ecology 69:693-702.

Chapin, F.S., III, G.R. Shaver, and R.A. Kedrowski. 1986. Environmental controls over carbon, nitrogen and phosphorus fractions in *Eriophorum vaginatum* in Alaskan tussock tundra. J. Ecol. 74:167-195.

Chapin, F.S., III., K. Van Cleve, and M.C. Chapin. 1979. Soil temperature and nutrient cycling in the tussock growth form of *Eriophorum vaginatum*. J. Ecol. 67:169-189.

Chapman, R.M., R.L. Detterman, and M.D. Mangus. 1964. Geology of the Killik-Etivluk rivers region, Alaska. Pages 325-407 *in* U.S. Geological Survey Professional Paper 303-F.

Church, M. 1974. Hydrology and permafrost with references to northern North America. Pages 7-20 *in* Permafrost Hydrology: Proceedings of a Workshop Seminar (1974). Canadian National Committee for the International Hydrological Decade. Ottawa, Ontario, Canada.

Churchill, E.D. 1955. Phytosociological and environmental characteristics of some plant communities in the Umiat region of Alaska. Ecology 36:606-627.

Cooper, D.J. 1986. Arctic-alpine tundra vegetation of the Arrigetch Creek Valley, Brooks Range, Alaska. Phytocoenologia 14:467-555.

Corps of Engineers. 1987. Corps of Engineers wetland delineation manual. Corps of Engineers Tech. Rep. Y-87-1. Dept. of the Army, Waterways Exp. Station, Vicksburg, MS. 100 pp.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep water habitats of the United States. U.S. Fish Wildl. Serv. FWS/OBS-79/31. 131 pp.

Crum, H. 1984. Sphagnopsida. Sphagnaceae. North America Flora Series, Part 11, New York Botanical Garden, 180 pp.

Damman, A.W.H. 1977. Geographical changes in the vegetation pattern of raised bogs in the Bay of Fundy region of Maine and New Brunswick. Vegetatio 35:137-151.

Damman, A.W.H. 1986. Hydrology, development, and biogeochemistry of ombrogenous peat bogs with special reference to nutrient relocation in a western Newfoundland bog. Can. J. Bot. 64:384-394.

Daubenmire, R. 1968. Plant communities: A textbook of plant synecology. Harper and Row, New York. 300 pp.

Detterman, R.L., A.L. Bowsher, and J.T. Dutro, Jr. 1958. Glaciation on the arctic slope of the Brooks Range, northern Alaska. Arctic 11:43-61.

Dick, W.A., and M.A. Tabatabai. 1979. Ion chromatographic determination of sulfate and nitrate in soils. Soil Science Society of America Journal 43:899-904.

Dick Peddie, W.A., J.V. Hardesty, E. Muldavin, and B. Sallach. 1987. Soil-vegetation correlations on the riparian zones of the Gila and San Francisco Rivers in New Mexico. U.S. Fish and Wildl. Serv. Biol. Rep. 87(9). 29 pp.

Dingman, S.L., R.G. Barry, G. Weller, C. Benson, E.F. LeDrew, and C.W. Goodwin. 1980. Climate, snow cover, microclimate, and hydrology. Pages 30-65 *in* J. Brown, et al., eds. An Arctic Ecosystem: The Coastal Tundra at Barrow, Alaska. Dowden, Hutchinson, & Ross, Stroudsburg, PA.

Drage, B., J.F. Gilman, D. Hoch, and L. Griffiths. 1983. Hydrology of North Slope coastal plain streams. Pages 249-254 *in* Fourth International Conference on Permafrost, Fairbanks, Alaska, July 17-22 1983, Proceedings. National Academy Press, Washington, DC.

Drew, J.W., and R.E. Shanks. 1965. Landscape relations of soils and vegetation in the forest-tundra ecotone, Upper Firth River valley, Alaska-Canada. Ecol. Monogr. 35:285-306.

Drury, W.H., Jr. 1956. Bog flats and physiographic processes in the Upper Kuskokwim River region, Alaska. The Gray Herbarium of Harvard University, Cambridge, MA. 127 pp.

Ebersole, J.J. 1985. Vegetation disturbance and recovery at the Oumalik Oil Well, Arctic Coastal Plain, Alaska. Ph.D. Dissertation. University of Colorado, Boulder. 408 pp.

Eicher, A.L. 1988. Soil-plant correlations in the tidal marshes and diked former tidelands of San Francisco Bay, California. U.S. Fish and Wildl. Serv. Biol. Rep. 88(21). 35 pp.

Elvebakk, A. 1985. Higher phytosociological syntaxa on Svalbard and their use in subdivision of the Arctic. Nor. J. Bot. 5:273-284.

Everett, K.R. 1980a. Landforms. Pages 14-19 *in* D.A. Walker, K.R. Everett, P.J. Webber, and J. Brown, eds. Geobotanical atlas of the Prudhoe Bay region, Alaska. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 80-14.

Everett, K.R. 1980b. Soils. Pages 20-23 *in* D.A. Walker, K.R. Everett, P.J. Webber, and J. Brown, eds. Geobotanical atlas of the Prudhoe Bay region, Alaska. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 80-14.

Everett, K.R. 1983. Summer wetlands in the frozen north. Geographical Magazine, Oct., pp. 510-515.

Everett, K.R. [1984]. Hydrology and wetland soils of arctic Alaska. Unpubl. report prepared for U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH. 107 pp.

Everett, K.R., G.M. Marion, and A.E. Linkins. 1989. Geochemistry of a small foothills watershed, arctic Alaska. Holarct. Ecol., in press.

Everett, K.R., and B. Ostendorf. 1988. Hydrology and geochemistry of a small drainage basin in upland tundra, Northern Alaska. Pages 574-579 *in* Fifth International Conference on Permafrost, Proceedings. National Academy Press, Washington, DC.

Everett, K.R., and R.J. Parkinson. 1977. Soil and landform associations, Prudhoe Bay area, Alaska. Arc. Alp. Res. 9:1-19.

Everett, K.R., V.D. Vassiljevskaya, J. Brown, and B.D. Walker. 1981. Tundra and analogous soils. Pages 139-179 *in* L.C. Bliss, O.W. Heal, and J.J. Moore, eds. Tundra ecosystems: a comparative analysis. Cambridge University Press, Cambridge, England.

Ford, J., and B.L. Bedford. 1987. The hydrology of Alaskan wetlands, U.S.A.: a review. Arc. Alp. Res. 19:209-229.

Foster, D.R., and P.H. Glaser. 1986. The raised bogs of south-eastern Labrador, Canada: classification, distribution, vegetation and recent dynamics. J. Ecol. 74:47-71.

Gauch, H.G. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge, MA. 298 pp.

Gee, G.W., and J.W. Bauder. 1986. Particle size analysis. Pages 383-411 *in* A. Klute, ed. Methods of soil analysis, Part I: Physical and mineralogical methods. Soil Science Society of America, Madison, WI.

Gjaerevoll, O. 1954. Kobresieto - Dryadion in Alaska. Nytt Mag. Bot. 1:51-54.

Gjaerevoll, O. 1968. Botanical investigations in central Alaska, especially in the White Mountains. Part III. Sympetalae. Kongel. Norske Vidensk. Selsk. Skr. 62 pp.

Gjaerevoll, O. 1980. A comparison between the plant communities of Alaska and Scandinavia. Acta Phytogeogr. Suec. 68:83-88.

Glaser, P.H. 1983. Vegetation patterns in the North Black River peatland, northern Minnesota. Can. J. Bot. 61:2085-2104.

Glaser, P.H., G.A. Wheeler, E. Gorham, and H.E. Wright, Jr. 1981. The patterned mires of the Red Lake peatland, northern Minnesota: vegetation, water chemistry and landforms. J. Ecol. 69:575-599.

Gore, A.J.P. 1961. Factors limiting plant growth on high-level blanket peat. I. Calcium and phosphate. J. Ecol. 49:399-402.

Gunnlaugsdottír, E. 1985. Composition and dynamical status of heathland communities in Iceland in relation to recovery measures. Acta Phytogeogr. Suec. 75:1-84.

Hamilton, T.D. 1986. Late Cenozoic glaciation of the Central Brooks Range. Pages 9-49 *in* T.D. Hamilton, K.M. Reed, and R.M. Thorson, eds. Glaciation in Alaska: the geologic record. Alaska Geological Society.

Hanson, H.C. 1951. Characteristics of some grassland, marsh, and other plant communities in western Alaska. Ecol. Monogr. 21:317-378.

Harlan, R.L. 1974. Dynamics of water movement in permafrost: A review. Pages 69-78 *in* Permafrost Hydrology: Proceedings of a Workshop Seminar (1974). Canadian National Committee for the International Hydrological Decade. Ottawa, Ontario, Canada.

Haugen, R.K. 1982. Climate of remote areas in north-central Alaska. 1975 - 1979 summary. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 80-14. 110 pp.

Hayward, P.M., and R.S. Clymo. 1982. Profiles of water content and pore size in *Sphagnum* and peat, and their relation to peat bog ecology. Proc. R. Soc. London Ser. B 215:299-325.

Heinselman, M.L. 1963. Forest sites, bog processes, and peatland types in the Glacial Lake Agassiz region, Minnesota. Ecol. Monogr. 33:327-372.

Heinselman, M.L. 1970. Landscape evolution, peatland types, and the environment in the Lake Agassiz Peatlands Natural Area, Minnesota. Ecol. Monogr. 40:235-261.

Hettinger, L.R., and A.J. Janz. 1974. Vegetation and soils of northeastern Alaska. Arctic Gas Biological Report Series Vol. 21. 206 pp.

Hill, M.O. 1979. DECORANA - A FORTRAN program for detrended correspondence analysis. Cornell University, Ithaca, NY.

Holmgren, B., C. Benson, and G. Weller. 1973. A study of the breakup on the arctic slope of Alaska by ground, air, and satellite observations. Pages 358-366 *in* G. Weller and S.A. Bowling, eds. Climate of the Arctic. Geophysical Institute, University of Alaska, Fairbanks.

Hultén, E. 1968. Flora of Alaska and neighboring territories. A manual of the vascular plants. Stanford University Press, Palo Alto, CA. 1008 pp.

Jackson, M.L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ. 498 pp.

Jeglum, J.K. 1971. Plant indicators of pH and water level in peatlands in Candle Lake, Saskatchewan. Can. J. Bot. 49:1661-1676.

Jenny, H. 1941. Factors of soil formation. McGraw-Hill, New York. 281 pp.

Jenny, H. 1961. Derivation of state factors equations of soils and ecosystems. Soil Sci. Soc. Am. Proc. 25:385-388.

Johnson, A.W. 1966. Vegetation and flora (of the Ogotoruk Valley). Pages 277-354 *in* N.J. Wilimovsky and J.N. Wolfe, eds.. Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Oak Ridge, TN.

Kane, D.L., and R.F. Carlson. 1973. Hydrology of the central arctic river basins of Alaska. Institute of Water Research, University of Alaska, Report no. IWR-41. 51 pp.

Kane, D.L., and L.D. Hinzman. 1988. Permafrost hydrology of a small arctic watershed. Pages 590 - 595 *in* Fifth International Conference on Permafrost, Proceedings. National Academy Press, Washington, DC.

Kane, D.L., R.D. Siefert, and G.S. Taylor. 1978. Hydrologic properties of subarctic organic soils. Institute of Water Resources, University of Alaska, Fairbanks. Report no. IWR-88. 49 pp.

Kane, D.L., and C.W. Slaughter. 1983. Water movement in seasonally frozen soils. Water Resour. Res. 19:1947-1557.

Keeney, D.R., and D.W. Nelson. 1982. Nitrogen--inorganic forms. Pages 643-698 *in* A.L. Page, R.H. Miller, and D.R. Keeney, eds. Methods of soil analysis, Part II: Chemical and microbiological properties. Soil Sci. Soc. Am. Madison, WI.

Keller, A.S., R.H. Morris, and R.L. Detterman. 1961. Geology of the Shaviovik and Sagavanirktok rivers region, Alaska. Pages 169-222 *in* U.S. Geological Survey Professional Paper 303-D.

Komárková, V., and P.J. Webber. 1980. Two Low Arctic vegetation maps near Atkasook, Alaska. Arc. Alp. Res. 12:447-472.

Koranda, J.J. 1960. The plant ecology of the Franklin Bluffs area, Alaska. Ph.D. Dissertation. University of Tennessee, Knoxville. 235 pp.

Kreig, R.A., and R.D. Reger. 1982. Air-photo analysis and summary of landform and soil properties along the route of the trans-Alaska pipeline system. Division of Geological and Geophysical Surveys, State of Alaska. Geologic Report 66.

Liston, G.E. 1986. Seasonal snowcover of the Foothills region of Alaska's Arctic Slope: A survey of properties and processes. M.S. Thesis. University of Alaska, Fairbanks. 123 pp.

Mackay, J.R., and D.K. MacKay. 1976. Cryostatic pressures in nonsorted circles (mud hummocks), Inuvik, Northwest Territories. Can. J. Earth Sci. 13:889-897.

Mark, A.F, N. Fetcher, G.R. Shaver, and F.S. Chapin, III. 1985. Estimated ages of mature tussocks of *Eriophorum vaginatum* along a latitudinal gradient in central Alaska, U.S.A. Arc. Alp. Res. 17:1-5.

Miller, P.C., P.M. Miller, B. Blake-Jacobson, F.S Chapin, III, K.R. Everett, D.W. Hilbert, J. Kummerow, A.E. Linkins, G.M. Marion, W.C. Oechel, S.W. Roberts, and L. Stuart. 1984. Plant-soil processes in *Eriophorum vaginatum* tussock tundra in Alaska: a systems modeling approach. Ecol. Monogr. 54:361-405.

Mueller Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York. 547 pp.

Nelson, D.W., and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. Pages 539-580 *in* A.L. Page, R.H. Miller, and D.R. Keeney, eds. Methods of soil analysis, Part II: Chemical and microbiological properties. Soil Sci. Soc. Am. Madison, WI.

Nyholm, E. 1954-1969. Illustrated moss flora of Fennoscandia (6 fascicles). Stockholm: Swedish Natural Science Research Council. 766 pp.

Odasz, A. 1983. Vegetation patterns at the treeline ecotone in the upper Alatna River drainage of the central Brooks Range, Alaska. Ph.D. Dissertation. University of Colorado, Boulder. 224 pp.

Oswood, M.W., and P. Flanagan. [1987]. Stream ecology, Imnavait Creek. Unpublished data report, Dept. of Energy R4D program. 25 pp.

Payne, T., S.W. Dana, G. Gryc, H. Tappan, R.H. Morris, E.H. Lathram, and P.D. Krynine. 1951. Geology of the Arctic Slope of Alaska. Oil and Gas Invest. Map OM 126, U.S. Geological Survey, Washington, DC.

Porter, S.C. 1964. Late Pleistocene glacial chronology of north-central Brooks Range, Alaska. Am. J. Sci. 262:446-460.

Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: Alaska (Region A). U.S. Fish and Wildl. Serv. Biol. Rep. 88(26.11). 86 pp.

Racine, C.H. 1981. Tundra fire effects on soils and three plant communities along a hill-slope gradient in the Seward Peninsula, Alaska. Arctic 34:71-84.

Racine, C.H., and J.H. Anderson. 1979. Flora and vegetation of the Chukchi-Imuruk area. Pages 38-113 *in* H.R. Melchior, eds. Biological survey of the Bering Land Bridge National Monument. Report to the U.S. Dept. of Interior, National Park Service, Contract no. CX-9000-3-0316.

Rawlinson, S.E. [1984]. Late Cenozoic geology of the Arctic Coastal Plain between the Colville and Canning Rivers. State of Alaska Dept. of Natural Resources, Division of Geological and Geophysical Surveys. Unpublished draft report. 12 pp.

Rieger, S., D.B. Schoephorster, and C.E. Furbish. 1979. Exploratory soil survey of Alaska. U.S. Department of Agriculture, Soil Conservation Service. 213 pp.

Rønning, O. 1965. Studies in the Dryadion of Svalbard. Norsk. Polarinst. Skr., 134:1-52.

Shaver, G.R., F.S. Chapin, III, and B.L. Gartner. 1986a. Factors limiting seasonal growth and peak biomass accumulation in *Eriophorum vaginatum* in Alaskan tussock tundra. J. Ecol. 74:257-278.

Shaver, G.R., N. Fetcher, and F.S. Chapin, III. 1986b. Growth and flowering in *Eriophorum vaginatum*: annual and latitudinal variation. Ecology 67:1524-1535.

Sipple, W.S. 1987. Wetland identification and delineation manual. Vol. I: Rationale, wetland parameters, and overview of jurisdiction approach. Vol. II: Field methodology. U.S. Environ. Prot. Agency, Washington, DC. 28 pp. and 29 pp.

Sjørs, H. 1948. Myrvegetation i Bergslagen. Acta Phytogeogr. Suec. 21:1-299.

Sjørs, H. 1950. On the relation between vegetation and electrolytes in north Swedish mire waters. Oikos 2:241-258.

Sjørs, H. 1963. Bogs and fens on Attawapiskat River, northern Ontario. Bull. Nat. Mus. Can. 186:45-103.

Soil Conservation Service. 1985. Hydric soils of the United States. U.S. Dept. Agric., Washington, DC.

Soil Survey Staff. 1975. Soil taxonomy, a basic system of soil classification for making and interpreting soil surveys. Soil Conservation Service, U.S. Department of Agriculture Handbook No. 436. 745 pp.

Spetzman, L.A. 1959. Vegetation of the Arctic Slope of Alaska. U.S. Geol. Surv. Prof. Pap. 302-B:19-58.

Steere, W.C. 1978. The mosses of Alaska. Germany: Strauss and Cramer. 508 pp.

Steere, W.C., and H. Inoue. 1978. The Hepaticeae of arctic Alaska. J. Hattori Bot. Lab. 44:251-345.

Tamm, C.O. 1954. Some observations on the nutrient turnover in a bog community dominated by *Eriophorum vaginatum* L. Oikos 5:189-194.

Tedrow, J.C.F. 1977. Soils of the polar landscapes. Rutgers University Press, New Brunswick, NJ. 638 pp.

Thomas, G.W. 1982. Exchangeable cations. Pages 159-166 *in* A.L. Page, R.H. Miller, and D.R. Keeney, eds. Methods of soil analysis, Part II: Chemical and microbiological properties. Soil Science Society of America, Madison, WI.

Thomson, J.W. 1979. Lichens of the Alaskan arctic slope. Univ. of Toronto Press, 314 pp.

Thomson, J.W. 1984. American arctic lichens. 1. The macrolichens. Columbia Univ. Press, New York. 504 pp.

Tiner, R. W. 1984. Wetlands of the United States: current status and recent trends. U.S. Dept. of Interior, Fish and Wildlife Service. 59 pp.

Vepraskas, M.J. and L.P. Wilding. 1983. Aquic moisture regime in soil with and without low chroma colors. Soil Sci. Soc. Am. J. 47:280-285.

Wahrhaftig, C. 1965. Physiographic divisions of Alaska. U.S. Geological Survey Professional Paper 482. 52 pp.

Walker, D.A. 1985. Vegetation and environmental gradients of the Prudhoe Bay region, Alaska. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 85-14. 239 pp.

Walker, D.A. [1988]. Terrain and vegetation types of the Sagavanirktok Quadrangle, Alaska. Unpublished report to NASA-Ames, Mountain View, CA, University Consortium Agreement no. NCA2-106. 56 pp.

Walker, D.A., and W. Acevedo. 1987. Vegetation and a Landsat-derived land cover map of the Beechey Point Quadrangle, Arctic Coastal Plain, Alaska. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 87-5. 63 pp. plus Map L-0211.

Walker, D.A., E. Binnian, B.M. Evans, N.D. Lederer, E. Nordstrand, and P.J. Webber. 1989. Terrain, vegetation, and landscape evolution of the R4D research site, Brooks Range Foothills, Alaska. Holarct. Ecol., in press.

Walker, D.A., and K.R. Everett. 1987. Road dust and its environmental impact in taiga and tundra. Arct. and Alp. Res. 19:479-489.

Walker, D.A., and K.R. Everett. Unpublished manuscript. Loess ecosystems of northern Alaska.

Walker, D.A., K.R. Everett, W. Acevedo, L. Gaydos, J. Brown, and P.J. Webber. 1982. Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, CRREL Report 82-27. 59 pp.

Walker, D.A., and N.D. Lederer. [1987]. Toposequence study: Site factors, soil physical and chemical properties, and plant species cover. Unpublished data report, Department of Energy R4D research program. 29 pp.

Walker, D.A., N.D. Lederer, and M.D. Walker. [1987.] Permanent vegetation plots: site factors, soil physical and chemical properties, and plant species cover. Unpubl. data report for R4D Program, U.S. Department of Energy.

Walker, D.A., and P.J. Webber. 1979. Relationships of soil acidity and air temperature to the wind and vegetation at Prudhoe Bay, Alaska. Arctic 32:224-236.

Walker, H.J. 1973. Morphology of the North Slope. Pages 49-92 *in* M.E. Britton, ed. Alaska arctic tundra. Arctic Institute of North America Technical Paper no. 25.

Walker, M.D. 1987. Vegetation and floristics of pingos, central arctic coastal plain, Alaska. Ph.D. Dissertation. University of Colorado, Boulder. 409 pp.

Washburn, A.L. 1956. Classification of patterned ground and review of suggested origins. Geol. Soc. Am. Bull. 67:823-866.

Washburn, A.L. 1973. Periglacial processes and environments. St. Martin's Press, New York. 320 pp.

Wentworth, T.R., and G.P. Johnson. 1986. Use of vegetation for the designation of wetlands. U.S. Fish Wildl. Serv., Washington, DC. 107 pp.

Westhoff, V., and E. van der Maarel. 1978. The Braun-Blanquet approach. Pages 287-399 *in* R.H Whittaker, ed. Classification of plant communities. The Hague, Junk.

Whittaker, R.H. 1948. A vegetation analysis of the Great Smoky Mountains. Ph.D. Dissertation, University of Illinois, Urbana. 210 pp.

Wiggins, I.L., and J.H. Thomas. 1962. A flora of the Alaskan Arctic Slope. Toronto Univ. Press, Toronto. 425 pp.

Williams, J.R., and R.O. van Everdingen. 1973. Groundwater investigations in permafrost regions of North America: A review. Pages 435-446 *in* Permafrost - North American Contribution to Second International Conference on Permafrost, Yakutsk, Siberia, July 13-18, 1973. National Academy of Sciences, Washington, DC.

Woo, M.K. 1982. Snow hydrology of the High Arctic. Pages 63-74 *in* Proceedings of the Joint Western/Eastern Snow Conference, April 20-23, Reno, NV.

APPENDIX A

Species Lists

Wetland indicator values are according to Reed (1988). Abbreviations are OBL - obligate wetland species; FACW - facultative wetland species; FAC - facultative species; FACU - facultative upland species; UPL - upland species. Vascular species marked with an asterisk (*) are not listed in Reed (1988).

<u>Vascular Species</u>

	Acomastylis rossii	FACU
	Aconitum delphinifolium ssp. *delphinifolium*	FAC
	Andromeda polifolia	FACW
*	*Anemone drummondii*	UPL
	Anemone parviflora	FACU
*	*Antennaria alpina* var. *media*	UPL
	Arctagrostis latifolia	FACW
	Arctous alpina	FAC
*	*Arnica lessingii*	UPL
*	*Artemisia arctica* ssp. *arctica*	UPL
*	*Astragalus umbellatus*	FACU
	Betula nana ssp. *exilis*	FAC
	Bistorta plumosa	FAC
	Bistorta vivipara	FAC
*	*Bupleurum triradiatum*	UPL
	Calamagrostis canadensis ssp. *canadensis*	FAC
	Calamagrostis inexpansa	FACW
*	*Campanula lasiocarpa*	UPL
	Cardamine pratensis ssp. *angustifolia*	OBL
	Carex aquatilis s.l.	OBL
	Carex bigelowii	FAC
	Carex microchaeta	FACU
	Carex misandra	FAC
*	*Carex obtusata*	UPL
	Carex podocarpa	FAC
	Carex rariflora	OBL
	Carex rotundata	OBL
	Carex rupestris	FACU
	Carex saxatilis ssp. *laxa*	FACW
	Carex scirpoidea	FACU
	Carex vaginata	OBL
	Cassiope tetragona ssp. *tetragona*	FACU
*	*Diapensia lapponica* ssp. *obovata*	UPL
	Dodecatheon frigidum	FACW

* *Douglasia ochotensis*	UPL
Dryas integrifolia ssp. *integrifolia*	FACU
* *Dryas octopetala* ssp. *octopetala*	UPL
Empetrum hermaphroditum	FAC
Equisetum arvense	FACU
Equisetum scirpoides	FACU
Equisetum variegatum ssp. *variegatum*	FACW
* *Erigeron muirii*	UPL
Eriophorum russeolum	FACW
Eriophorum scheuchzeri ssp. *scheuchzeri*	OBL
Eriophorum triste	OBL
Eriophorum vaginatum	FACW
* *Eritrichum aretioides*	UPL
Festuca altaica	FAC
Gentiana glauca	FAC
* *Hierochloë alpina*	UPL
Hippuris vulgaris	OBL
* *Huperzia selago* ssp. *appressa*	UPL
Juncus biglumis	OBL
Kobresia myosuroides	FAC
Ledum palustre ssp. *decumbens*	FACW
* *Loiseleuria procumbens*	UPL
Luzula arctica	FAC
Luzula confusa	FAC
Luzula wahlenbergii	OBL
* *Minuartia arctica*	UPL
Minuartia obtusiloba	FACU
* *Novosieversia glacialis*	FACU
* *Orthilia secunda* ssp. *obtusata*	UPL
* *Oxytropis nigrescens s.l.*	UPL
Papaver macounii	FACU
* *Parrya nudicaulis s.l.*	FACU
Pedicularis albolabiata	FACW
Pedicularis capitata	FACU
Pedicularis labradorica	FACW
Pedicularis langsdorfii	FACW
Pedicularis lapponica	FAC
Petasites frigidus	FAC
Phlox sibirica ssp. *sibirica*	UPL
Poa arctica	FAC
* *Poa glauca*	UPL
Poa lanata	FACU
* *Poa paucispicula*	FACU
Polemonium acutiflorum	FAC
Potentilla palustris	OBL
* *Potentilla uniflora*	UPL
Pyrola grandiflora	FAC
Rhododendron lapponicum	FAC
Rubus chamaemorus	FACW
Salix arctica	FAC
Salix chamissonis	FACW

	Salix fuscescens	FACW
	Salix phlebophylla	FACU
	Salix planifolia ssp. *pulchra*	FACW
	Salix reticulata ssp. *reticulata*	FAC
	Salix rotundifolia ssp. *rotundifolia*	UPL
	Saussurea angustifolia	FAC
	Saxifraga bronchialis ssp. *funstonii*	FACU
	Saxifraga cernua	FACW
	Saxifraga foliolosa	FACW
	Saxifraga nelsoniana	FAC
*	*Saxifraga nivalis*	UPL
	Saxifraga rivularis	OBL
	Saxifraga tricuspidata	FACU
*	*Selaginella sibirica*	UPL
	Senecio atropurpureus ssp. *frigidus*	FAC
*	*Silene acaulis*	UPL
*	*Smelowskia calycina*	UPL
	Sparganium hyperboreum	OBL
	Stellaria longipes	FAC
	Tofieldia pusilla	FAC
	Trisetum spicatum ssp. *spicatum*	FAC
	Vaccinium uliginosum	FAC
	Vaccinium vitis-idaea ssp. *minus*	FAC
	Valeriana capitata	FAC

Bryophyte Species

Anastrophyllum minutum	FACW
Aneura pinguis	FACW
Aulacomnium palustre	FACW
Aulacomnium turgidum	FACW
Blepharostoma trichophyllum ssp. *brevirete*	FACW
Brachythecium groenlandicum	FACW
Brachythecium turgidum	OBL
Bryum algovicum	FAC
Bryum pseudotriquetrum	FAC
Calliergon giganteum	OBL
Calliergon sarmentosum	OBL
Calliergon stramineum	OBL
Campylium stellatum	OBL
Ceratodon purpureus	FAC
Chandonanthus setiformis	FACU
Cirriphyllum cirrosum	FACW
Dicranum acutifolium	FACU
Dicranum angustum	FAC
Dicranum elongatum	FAC
Dicranum groenlandicum	FAC
Dicranum muehlenbeckii	FACW
Dicranum scoparium	FAC
Dicranella varia	FAC

Diplophyllum opacifolia	FAC
Drepanocladus badius	OBL
Drepanocladus revolvens	OBL
Drepanocladus uncinatus	FAC
Gymnomitrion concinnatum	FACW
Hylocomium splendens ssp. *obtusifolium*	FACW
Hypnum bambergeri	FACW
Lophozia binsteadii	FACW
Lophozia guttulata	FAC
Lophozia quadriloba	FACW
Meesia uliginosa	FACW
Mylia anomala	FACW
Paludella squarrosa	OBL
Plagiomnium medium	FAC
Pleurozium schreberi	FACW
Pogonatum urnigerum	FACU
Pohlia andrewsii	FAC
Pohlia crudoides	FAC
Pohlia elongata	FACW
Pohlia nutans	FACW
Polytrichastrum alpinum	FACW
Polytrichum commune	FAC
Polytrichum hyperboreum	UPL
Polytrichum longisetum	FACW
Polytrichum piliferum	UPL
Polytrichum sexangulare	FACW
Polytrichum strictum	FACW
Polytrichum swartzii	OBL
Pseudobryum cinclidioides	OBL
Pseudolepicola fryei	OBL
Ptilidium ciliare	FAC
Ptilium cristum-castrensis	FAC
Radula prolifera	FACW
Rhacomitrium lanuginosum	FACU
Rhizomnium andrewsianum	OBL
Rhytidium rugosum	FACU
Scapania paludicola	OBL
Scapania simsonii	FACW
Sphagnum angustifolium	OBL
Sphagnum aongstroemii	OBL
Sphagnum balticum	OBL
Sphagnum compactum	OBL
Sphagnum fimbriatum	FACW
Sphagnum girgensohnii	OBL
Sphagnum imbricatum	OBL
Sphagnum lenense	FACW
Sphagnum lindbergii	OBL
Sphagnum magellanicum	FACW
Sphagnum nemoreum	FACW
Sphagnum obtusum	OBL
Sphagnum orientale	OBL

Sphagnum rubellum	FACW
Sphagnum squarrosum	OBL
Sphagnum subsecundum	OBL
Sphagnum teres	OBL
Sphagnum warnstorfii	OBL
Thuidium abietinum	FACU
Tomenthypnum nitens	FAC
Tortula ruralis	FACU
Tritomaria quinquedentata	FACU

Lichen Species

Alectoria nigricans	UPL
Alectoria ochroleuca	UPL
Asahinea chrysantha	FACU
Cetraria andrejevii	OBL
Cetraria commixta	FACU
Cetraria cucullata	FAC
Cetraria delisei	FACW
Cetraria fastigiata	FAC
Cetraria islandica	FACU
Cetraria kamczatica	FACU
Cetraria laevigata	FAC
Cetraria nigricans	FACU
Cetraria nivalis	FACU
Cetraria richardsonii	FAC
Cetraria tilesii	FACU
Cladonia alaskana	FACU
Cladonia amaurocraea	FAC
Cladonia arbuscula	FAC
Cladonia carneola	FACU
Cladonia cenotea	FACU
Cladonia chlorophaea	FACU
Cladonia coccifera	FAC
Cladonia cornuta	FACU
Cladonia deformis	FAC
Cladonia ecmocyna	FAC
Cladonia fimbriata	FACU
Cladonia gracilis	FACU
Cladonia macrophylla	FACU
Cladonia mitis	FAC
Cladonia pleurota	FACU
Cladonia pocillum	FACU
Cladonia pyxidata	FACU
Cladonia rangiferina	FAC
Cladonia stellaris	FAC
Cladonia subulata	FACU
Cladonia sulphurina	FAC
Cladonia uncialis	FAC
Cornicularia aculeata	FACU

Cornicularia divergens	FACU
Dactylina arctica	FAC
Dactylina beringica	FAC
Dactylina ramulosa	FAC
Dermatocarpon lachneum	FACU
Hypogymnia subobscura	UPL
Lecidea demissa	FAC
Lecanora epibryon	FACU
Lobaria linita	FACU
Mycoblastis sanguinarius	FACU
Nephroma arcticum	FACU
Nephroma expallidum	FACU
Ochrolechia frigida	FACU
Ochrolechia upsaliensis	UPL
Peltigera aphthosa	FAC
Peltigera canina	FACU
Peltigera horizontalis	FAC
Peltigera leucophlebia	FAC
Peltigera malacea	FAC
Peltigera polydactyla	FAC
Peltigera scabrosa	FAC
Pertusaria bryontha	UPL
Pertusaria dactylina	UPL
Pertusaria panyrga	UPL
Polyblastia gelatinosa	FAC
Psoroma hypnorum	FACU
Solorina bispora	FAC
Solorina crocea	FAC
Solorina saccata	FACW
Sphaerophorus globosus	UPL
Stereocaulon paschale	UPL
Stereocaulon tomentosum	UPL

Appendix B-1. Typical profile of a Pergelic Cryofibrist. The soil and site are in Figure 4.

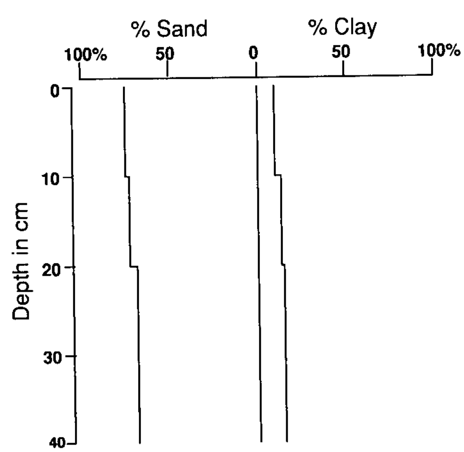
PLOT: SW-16

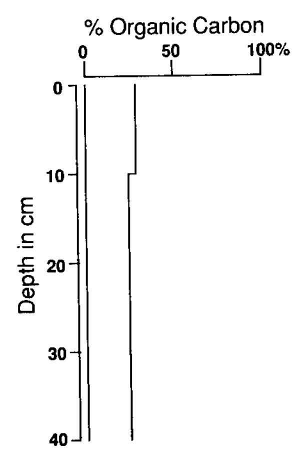
MICROSITE: Stream channel

VEGETATION: Aquatic *Carex aquatilis, Eriophorum angustifolium* sedge tundra

NOTES: Permafrost at 72 cm; soil has deep mat of organic material with large amount of included sandy alluvium

Oi1	0-10 cm	Very dark reddish brown (5 YR 2/4) loose sandy loamy fibric peat composed of roots and sedge leaves; many fine and very fine live roots; gradual smooth boundary
Oi2	10-20 cm	Very dark brown (7.5 YR 2/3) compressed sandy loamy fibric peat composed of roots and sedge leaves; many fine and very fine roots; gradual smooth boundary
Oi3	20-40+ cm	Brownish black (10 YR 2/3) compacted sandy loam peat





Appendix B-2. Typical profile of a Hemic Pergelic Sphagnofibrist. The soil and site are in Figure 5.

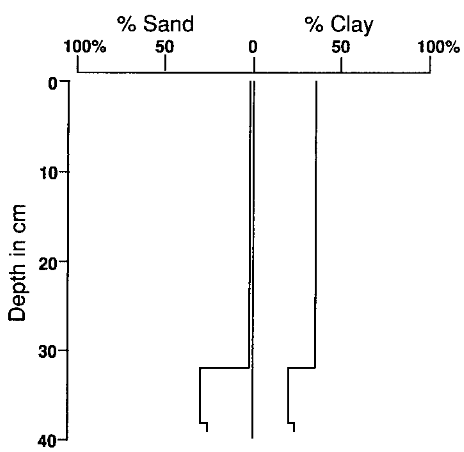
PLOT: SW-24

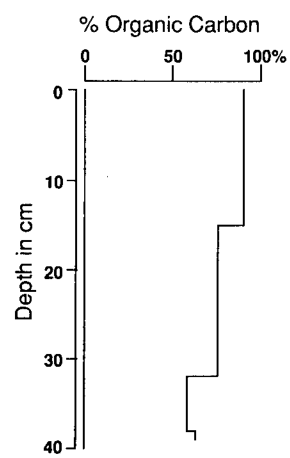
MICROSITE: Palsa in colluvial basin

VEGETATION: Moist *Betula nana, Rubus chamaemorus, Ledum palustre* ssp. *decumbens, Dicranum elongatum, Sphagnum* spp., *Cladonia* spp. dwarf-shrub, fruticose-lichen tundra

NOTES: Permafrost at 39 cm, water table at 38 cm

Oi	0-15 cm	Bright reddish brown to yellow orange (5 YR 5/8 to 10 YR 8/4) very porous loose fibric peat composed of Sphagnum bases; clear smooth boundary
Oe	15-32 cm	Brownish black (5 YR 2/2) compressed hemic Sphagnum peat; loam mineral component less than 2% by volume; moderate medium platey structure; many fine and very fine roots; abrupt smooth boundary
Oa	32-39+ cm	Very dark brown (7.5 YR 2/3) sapric Sphagnum peat; loam mineral component approximately 10% by volume; moderate medium granular structure; slightly sticky, slightly plastic; many fine and very fine roots binding the soil, common fine roots below water table at 38 cm





Appendix B-3. Typical profile of a Pergelic Cryohemist. The soil and site are in Figure 6.

PLOT: SW-22A

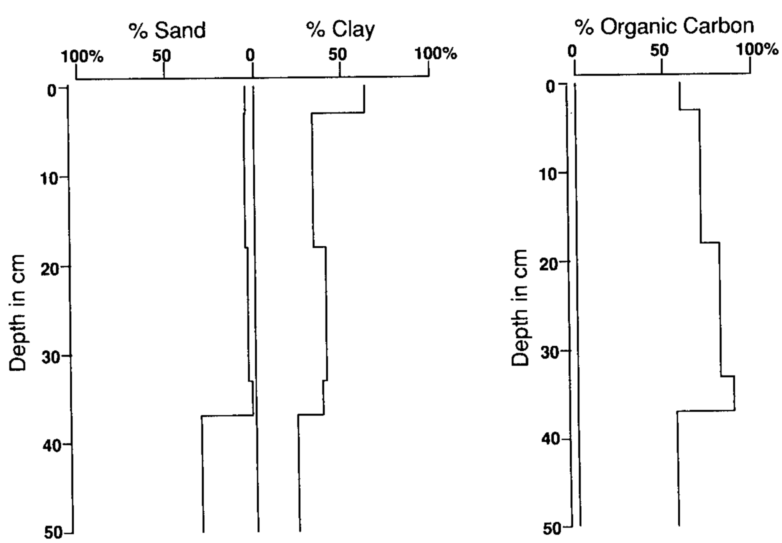
MICROSITE: Bog in colluvial basin, inter-hummock site

SUBSTRATE: Organic-rich basin deposit

VEGETATION: Wet *Carex rariflora, C. rotundata, Eriophorum scheuchzeri, Sphagnum lindbergii* sedge tundra

NOTES: Permafrost at 48 cm; discontinuity (and water table) at 37 cm, possibly overlying a buried peat

IOi1	0-3 cm	Brownish black (5 YR 2/2) loose organic mat composed of Sphagnum and sedge roots; very dark reddish brown (5 YR 3/2) clay component, approximately 5% by volume; slightly sticky, slightly plastic; clear smooth boundary
IOi2	3-18 cm	Dark brown (7.5 YR 3/3) compressed hemic peat with silty clay loam mineral component, approximately 5% by volume; not sticky, not plastic; many fine and very find roots; clear smooth boundary
IOe1	18-33 cm	Very dark brown (7.5 YR 2/3) fibric peat with many yellowish sedge roots; clear smooth boundary
IOe2	33-37 cm	Very dark brown (7.5 YR 2/3) more compressed fibric peat; silty clay loam component approximately 10% by volume; slightly sticky, slightly plastic; many fine and very fine roots; abrupt smooth boundary
IIOa	37-48+ cm	Very dark brown (7.5 YR 2/3) sapric peat; loam component approximately 20% by volume; extremely wet; moderate medium subangular blocky structure breaking to weak medium granular; few fine roots



Appendix B-4. Typical profile of a Pergelic Cryochrept. The soil and site are in Figure 7.

PLOT: SW-33

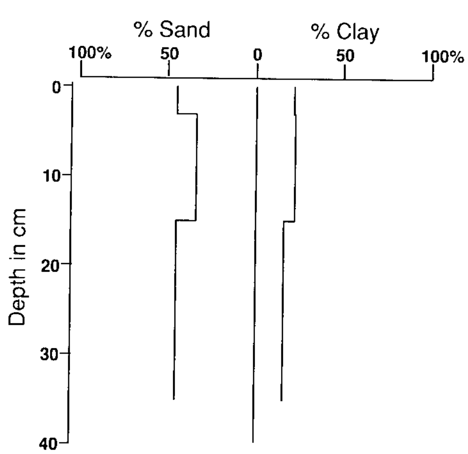
MICROSITE: Sandstone outcrop with 2-5% cover of rounded glacial erratics, stable ground surface, no evidence of cryoturbation

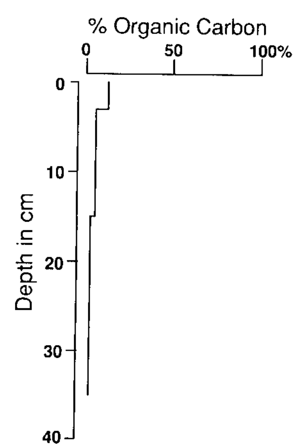
SUBSTRATE: Sandstone rubble

VEGETATION: Dry *Dryas octopetala, Salix phlebophylla, Selaginella sibirica, Antennaria friesiana, Cetraria cucullata* dwarf-shrub, fruticose-lichen tundra

NOTES: Permafrost depth unknown

Oa	0-3 cm	Brownish black (10YR 2/3) gravelly organic loam; moderate fine granular structure; approximately 20% fine gravel fragments with occasional cobbles; friable, slightly sticky, slightly plastic; many fine and very fine roots; clear smooth boundary
Bw1	3-15 cm	Dark brown (10 YR 4/4) gravelly loam; weak medium subangular blocky structure breaking to moderate fine granular; approximately 20% gravel fragments to 3 cm diameter with occasional angular cobbles to 10 cm diameter; friable; slightly sticky, slightly plastic; many fine and very fine roots; clear smooth boundary
Bw2	15-35 cm	Brown (10 YR 4/5) cobbly loam; weak subangular blocky structure breaking to moderate fine granular; approximately 75% gravel and angular cobbles up to 12 cm diameter; friable; slightly sticky, slightly plastic; silt caps on tops of cobbles to 1 mm thick; continuous iron (2.5 YR 3/4) and manganese (5 YR 2/1) coats on bottoms of cobbles; common fine roots





Appendix B-5. Typical profile of a Pergelic Cryaquept. The soil and site are in Figure 8.

PLOT: SW-8

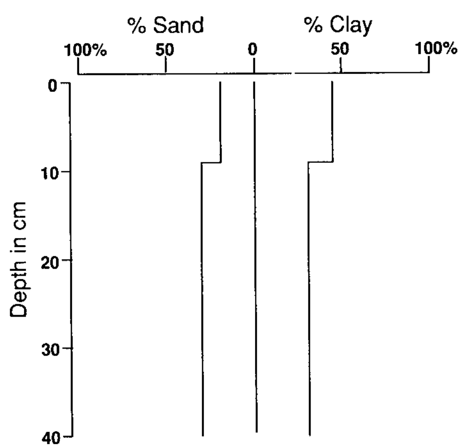
MICROSITE: Interfluve between water tracks, about midslope

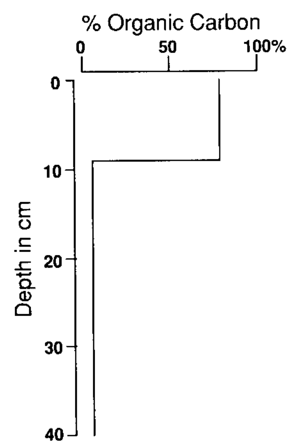
SUBSTRATE: Clay-rich Sagavanirktok-age till

VEGETATION: Moist *Carex bigelowii, Betula nana, Ledum palustre* spp. *decumbens, Sphagnum* spp. sedge, dwarf-shrub tundra

NOTES: Permafrost at 40 cm

Oe	0-9 cm	Black (5 YR 1.7/1) coarse hemic peat; many fine and very fine roots; abrupt smooth boundary
Bw	9-40+ cm	Dull brown (7.5 YR 5/4) gravelly sandy clay loam; moderate medium subangular blocky structure, breaking to moderate fine granular; approximately 20% gravel less than 2.5 cm diameter; sticky, plastic; many fine and very fine roots





Appendix B-6. Typical profile of a Histic Pergelic Cryaquept. The site and soil are in Figure 9.

PLOT: SW-6

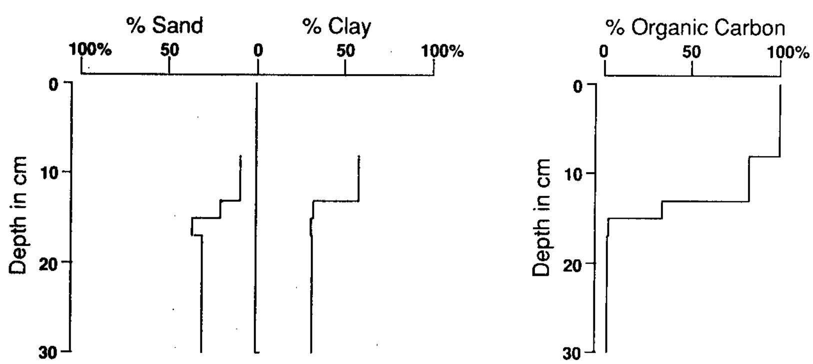
MICROSITE: Interfluve between water tracks, weakly-developed solifluction features about middle of backslope

SUBSTRATE: Clay-rich Sagavanirktok-age till

VEGETATION: Moist *Carex bigelowii, Betula nana, Salix planifolia* ssp. *pulchra, Ledum palustre* ssp. *decumbens, Hylocomium splendens, Sphagnum* spp. sedge, dwarf-shrub tundra

NOTES: Permafrost at 30 cm; oxidized mineral layer at base of peat

Oi	0-8 cm	Bright yellow brown (10 YR 6/6) loose fibric peat composed of live moss bases (Sphagnum and Hylocomium) and other plant roots; clear smooth boundary
Oe	8-13 cm	Black (7.5 YR 1.7/1) hemic peat; moderate medium platey structure; 10%-15% mineral, mostly clay; many fine and very fine roots; abrupt smooth boundary
Oa	13-15 cm	Brown (7.5 YR) organic sandy clay loam; weak medium platey structure breaking to fine granular; noticeable increase in clay toward base of organics; slightly sticky, slightly plastic; many fine and very fine roots, common medium roots; abrupt smooth boundary
Bw	15-30+ cm	Grayish yellow brown (10 YR 4/2) clay loam with prominent medium to large irregularly-shaped brown (10 YR 4/6) mottles concentrated along root channels, plant material and areas of somewhat sandier soil; bright brown (7.5 YR 5/6) oxidized band 1-2 cm thick at top of horizon beneath overlying peat; moderate medium angular blocky structure; 5%-10% fine gravel, less than 1 cm diameter; sticky, plastic; many fine and very fine roots



Appendix C-1. Sorted table of dry communities.

PLOT NUMBER	63	64	58A	54	53	52	42	33	51	60	28	38	09	FREQ
Taxa occurring in blockfields to moist habitats (Groups 1 to 4)														
Polytrichum strictum	.	R	.	.	.	1	.	1	2	1	R	.	2	7
Cetraria cucullata	R	.	R	R	R	1	R	R	2	2	1	1	R	12
Cetraria islandica	R	R	R	R	R	R	+	R	R	R	R	1	1	13
Cladonia amaurocraea	R	1	.	R	.	R	R	R	1	R	R	R	R	11
Dactylina arctica	.	R	.	.	.	.	R	R	R	.	.	R	R	6
Cladonia gracilis	1	1	.	.	.	.	R	.	1	R	R	1	1	8
Cladonia rangiferina	1	1	.	.	.	.	R	.	2	R	.	.	.	5
Vaccinium uliginosum	.	R	.	.	.	.	R	.	3	3	1	.	.	5
Thamnolia spp.	R	R	1	1	2	1	R	R	R	1	R	R	R	13
Cetraria nivalis	1	R	R	1	1	2	1	R	1	R	2	2	3	13
Cladonia arbuscula	1	1	.	.	.	.	1	.	2	+	.	R	.	6
Poa arctica	.	R	.	.	.	.	R	.	R	.	.	.	.	3
Taxa occurring in blockfields and dry habitats														
Alectoria ochroleuca	1	1	2	+	R	.	1	1	.	.	1	1	1	10
Sphaerophorus globosus	1	R	1	R	.	.	1	1	.	.	.	2	2	8
Cornicularia divergens	2	2	2	1	1	R	2	2	.	.	2	1	2	11
Cladonia uncialis	R	R	.	R	.	.	1	R	.	.	.	R	.	6
Dicranum acutifolium	R	R	.	.	.	.	.	R	.	1	.	R	.	5
Alectoria nigricans	R	R	R	R	.	.	1	2	.	.	.	1	.	7
Rhacomitrium lanuginosum	1	1	R	.	.	.	.	1	.	.	1	.	.	5
Cladonia coccifera	R	.	.	.	.	.	R	.	.	R	.	R	R	5
Chandonanthus setiformis	2	1	.	.	.	.	.	.	.	.	.	.	.	2
Psoroma hypnorum	.	R	R	.	.	.	.	R	.	.	.	R	.	4
Cladonia macrophylla	.	.	.	.	.	.	.	.	.	.	.	R	R	2
Cladonia pyxidata	.	R	.	.	.	R	.	.	1	.	.	.	.	3
Lecidea demissa	.	.	.	.	.	.	R	.	.	.	.	.	R	2
Group 1: Blockfields (*Rhizocarpon geographicum - Cetraria nigricans*)														
Rhizocarpon geographicum	2	1	R	.	.	.	.	R	.	.	1	R	.	6
Cetraria nigricans	2	1	.	.	R	.	R	R	.	.	R	.	R	7
Xanthoria centrifuga	1	2	.	.	.	.	.	.	.	.	.	.	.	2
Umbilicaria proboscidea	1	1	.	.	.	.	.	.	.	.	R	.	.	3
Lecidea flavocaerulescens	1	1	.	.	.	.	.	R	.	.	.	.	.	3
Parmelia omphalodes	R	1	R	R	.	.	.	.	.	.	R	R	.	6
Haematomma lapponicum	R	.	.	.	.	.	.	.	.	.	.	R	.	2
Umbilicaria hyperborea	.	1	R	.	.	.	.	.	.	.	.	R	.	3
Taxa occurring in dry to moist habitats (Groups 2 to 5)														
Vaccinium vitis-idaea ssp. *minus*	.	.	.	.	.	.	1	1	1	1	1	2	R	7
Cetraria richardsonii	.	.	.	.	.	R	1	R	1	R	.	R	R	7
Peltigera aphthosa	.	.	R	R	.	R	R	R	.	.	.	.	.	5
Dicranum elongatum	.	.	.	.	.	.	1	.	.	1	1	2	.	4
Cladonia mitis	.	.	.	.	.	.	.	.	.	+	.	R	R	3
Taxa occurring in dry habitats (Groups 2 to 4)														
Stereocaulon tomentosum	.	.	.	1	1	1	1	R	1	2	.	R	.	8
Asahinea chrysantha	.	.	1	R	R	.	1	1	.	.	R	R	.	7
Salix phlebophylla	.	.	.	.	R	1	2	1	1	.	2	.	2	7
Pertusaria dactylina	.	.	.	.	R	.	1	R	.	.	.	R	R	5
Polytrichum piliferum	.	.	R	+	R	.	R	1	.	.	1	R	R	8
Hypogymnia subobscura	.	.	.	+	1	.	1	R	.	.	1	.	.	5
Artemisia arctica ssp. *arctica*	.	R	.	.	.	1	R	R	R	R	.	.	.	6
Rhytidium rugosum	.	.	.	.	.	1	1	R	1	3	.	.	.	5
Pertusaria panyrga	.	.	.	.	.	.	.	.	.	.	R	.	R	2
Polytrichum hyperboreum	.	.	.	.	.	.	1	R	.	.	.	1	.	3
Pseudephebe pubescens	.	.	.	.	R	.	.	.	.	.	2	.	.	2
Cladonia alaskana	.	.	.	.	.	.	.	1	.	R	.	.	.	2

(Continued)

Appendix C-1. Concluded

PLOT NUMBER	63	64	58A	54	53	52	42	33	51	60	28	38	09	FREQ
Group 2: Exposed sandstone outcrops, till (*Dryas octopetala - Selaginella sibirica*)														
Dryas octopetala ssp. *octopetala*	.	.	4	3	3	3	3	3	R	2	.	.	.	8
Selaginella sibirica	.	.	R	+	1	1	1	R	.	.	.	.	.	6
Minuartia obtusiloba	.	.	R	R	+	+	R	.	.	.	.	.	.	5
Xanthoria separata	.	R	R	R	R	.	1	R	.	.	R	R	.	8
Antennaria alpina var. *media*	.	.	.	R	R	R	R	R	.	.	.	.	.	5
Saxifraga bronchialis ssp. *funstonii*	.	.	.	R	.	R	R	R	.	.	.	.	.	4
Poa glauca	.	.	.	R	R	R	R	.	.	R	.	.	.	5
Saxifraga nivalis	.	.	R	.	R	1	R	.	.	R	.	.	.	5
Cornicularia aculeata	.	.	.	R	R	.	.	R	.	.	.	.	.	3
Carex rupestris	.	.	R	.	.	.	1	.	.	.	.	.	.	2
Subgroup 2A: *Dryas octopetala - Oxytropis nigrescens* (depauperate)														
Oxytropis nigrescens s.l.	.	.	R	1	R	R	.	.	.	.	.	.	.	4
Smelowskia calycina	.	.	R	R	+	R	.	.	.	.	.	.	.	4
Kobresia myosuroides	.	.	.	1	1	1	.	.	.	R	.	.	.	4
Douglasia ochotensis	.	.	R	R	+	.	.	.	.	.	.	.	.	3
Ochrolechia upsaliensis	.	.	1	.	1	R	.	.	.	.	.	.	.	3
Solorina bispora	.	.	.	R	R	.	.	.	.	.	.	.	.	2
Community type *Dryas octopetala - Carex obtusata*														
Carex obtusata	.	.	.	.	R	R	.	.	.	.	.	.	.	2
Potentilla uniflora	.	.	.	.	R	R	.	.	.	.	.	.	.	2
Saxifraga tricuspidata	.	.	.	.	R	R	.	.	.	.	.	.	.	2
Bupleurum triradiatum	.	.	.	.	R	1	R	.	.	.	.	.	.	3
Encalypta rhaptocarpa	.	.	.	.	1	1	.	.	.	.	.	.	.	2
Peltigera canina	.	.	.	.	R	R	.	.	.	.	.	.	.	2
Subgroup 2B: *Dryas octopetala - Vaccinium vitis-idaea*														
Encalypta brevicola	.	.	.	.	.	.	+	R	.	.	.	.	.	2
Group 3: Shallow snow areas (*Arctous alpina - Hierochloë alpina*)														
Arctous alpina	.	.	.	.	.	.	.	R	2	2	2	4	3	6
Hierochloë alpina	R	R	.	.	.	.	+	1	+	1	R	1	1	9
Community type *Vaccinium uliginosum - Arctous alpina*														
Peltigera malacea	.	.	.	.	.	.	.	.	1	R	.	.	.	2
Other species														
Bistorta plumosa	.	.	.	.	.	.	R	.	R	R	.	.	R	4
Cladonia pleurota	.	R	.	.	.	.	.	.	.	.	.	R	.	2
Cassiope tetragona ssp. *tetragona*	.	R	.	.	.	.	.	.	.	.	R	.	R	3
Ledum palustre ssp. *decumbens*	.	.	.	.	.	.	.	.	.	.	1	.	1	2
Anastrophyllum minutum	.	.	.	.	.	.	.	.	.	.	R	R	.	2
Pedicularis capitata	.	.	.	.	.	R	.	.	R	+	.	.	.	3
Stellaria longipes	.	.	.	.	.	.	.	.	R	R	.	.	.	2
Pedicularis langsdorffii	.	.	.	.	.	.	R	.	R	.	.	R	.	3
Carex microchaeta	.	.	.	.	.	.	R	R	.	1	R	R	.	5
Pohlia nutans	.	.	.	.	.	.	.	.	.	.	.	R	R	2
Arnica lessingii	.	.	.	.	.	1	.	R	.	.	.	.	.	2
TOTAL SPECIES FREQUENCY	32	39	35	36	46	38	54	53	30	37	34	43	38	
PLOT NUMBER	63	64	58A	54	53	52	42	33	51	60	28	38	09	

SINGLE OCCURENCES (PLOT NUMBER: SPECIES): Plot 63: *Umbilicaria caroliniana, Ochrolechia frigida, Parmelia stygia, Dactylina beringica*; Plot 64: *Cetraria hepatizon, Parmelia sulcata, Dactylina ramulosa, Polytrichastrum alpinum*; Plot 58A: *Cetraria commixta*; Plot 54: *Dermatocarpon lachneum, Rinodina turfacea, Dicranum muehlenbeckii*; Plot 53: *Anemone drummondii, Eritrichum aretioides, Erigeron muirii, Senecio atropurpureus* ssp. *frigidus, Pogonatum urnigerum, Lecanora epibryon*; Plot 52: *Caloplaca jungermanniae*; Plot 42: *Nephroma expallidum, Lobaria linita, Mycoblastis sanguinarius*; Plot 33: *Cetraria andrejevii, Empetrum hermaphroditum, Bryum algovicum, Cladonia pocillum, Pertusaria bryontha, Minuartia arctica*; Plot 51: *Cladonia chlorophaea*; Plot 60: *Carex misandra, Poa lanata, Saxifraga nelsoniana, Festuca altaica*; Plot 28: *Diapensia lapponica* ssp. *obovata, Asahinea scholanderi*; Plot 38: *Lophozia guttulata, Tortula ruralis*; Plot 09: *Betula nana* ssp. *exilis, Luzula confusa, Eriophorum vaginatum, Carex bigelowii, Tritomaria quinquedentata, Ceratodon purpureus*

Appendix C-2. Sorted table of snowbed communities.

PLOT NUMBER	43	39	29A	30A	32A	44A	41	40	57	56	55	59	26	72	73	69	70	71	FREQ
Taxa occurring in blockfields to moist habitats (Groups 1 to 5)																			
Polytrichum strictum	1	R	.	.	1	2	.	1	.	.	.	.	1	.	.	.	.	.	6
Cetraria cucullata	1	1	2	1	1	2	2	.	1	1	1	1	1	.	.	.	.	.	12
Cetraria islandica	R	1	1	R	.	R	1	1	R	+	+	1	R	.	R	.	.	.	13
Cladonia amaurocraea	R	R	R	R	R	R	.	R	1	+	1	R	R	.	.	.	.	.	12
Dactylina arctica	R	R	1	1	R	R	.	.	+	+	1	1	R	.	.	.	.	.	11
Cladonia gracilis	R	1	1	1	1	R	1	2	1	1	1	R	R	R	.	.	.	.	14
Cladonia rangiferina	1	1	2	2	2	2	1	2	2	1	1	R	2	.	.	.	R	.	14
Vaccinium uliginosum	R	R	1	1	1	R	R	.	2	.	1	2	2	.	.	.	.	.	11
Thamnolia spp.	1	R	R	R	R	R	R	R	R	+	R	1	R	.	.	R	R	.	15
Cetraria nivalis	2	2	1	1	R	1	.	R	R	R	1	1	2	.	.	.	.	.	12
Cladonia arbuscula	R	2	.	2	R	1	2	2	2	.	2	R	2	.	.	.	.	.	11
Poa arctica	.	.	.	.	.	.	R	.	.	R	.	.	R	R	+	.	.	.	5
Taxa occurring in blockfields and dry habitats (Groups 1 to 4)																			
Alectoria ochroleuca	2	1	1	R	.	1	.	.	R	R	.	R	1	.	.	.	.	.	9
Sphaerophorus globosus	2	1	R	R	R	2	.	.	R	.	R	.	1	.	.	.	.	.	9
Cornicularia divergens	2	1	.	.	.	R	.	.	.	R	.	.	.	.	.	.	.	.	4
Cladonia uncialis	R	R	R	R	R	R	R	R	1	.	.	.	R	R	.	.	.	.	11
Dicranum acutifolium	.	R	.	.	2	1	1	3	R	R	2	R	R	.	.	.	.	.	10
Alectoria nigricans	.	R	.	R	.	R	R	.	.	.	.	.	R	.	.	.	.	.	5
Rhacomitrium lanuginosum	.	R	.	R	1	2	.	1	2	.	1	.	R	R	.	.	.	.	9
Cladonia coccifera	.	R	R	.	R	.	R	R	.	.	.	.	.	.	.	.	.	.	5
Chandonanthus setiformis	R	.	.	.	.	R	.	1	R	.	R	.	R	R	.	.	.	.	7
Psoroma hypnorum	.	.	.	.	.	.	R	R	R	.	.	.	.	R	.	.	.	.	4
Cladonia macrophylla	R	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	2
Taxa occurring in dry to moist habitats (Groups 2 to 5)																			
Vaccinium vitis-idaea ssp. *minus*	2	3	1	1	1	2	R	1	2	2	3	.	R	.	.	.	R	.	13
Cetraria richardsonii	1	R	R	R	R	R	R	R	1	1	1	1	R	.	+	.	.	.	14
Peltigera aphthosa	.	.	R	R	R	R	.	.	+	+	1	.	R	R	.	.	.	.	9
Dicranum elongatum	1	2	.	.	.	.	R	2	2	1	.	.	R	.	.	.	.	.	7
Cladonia mitis	.	.	1	.	R	.	.	.	.	.	.	R	.	.	.	.	.	.	3
Taxa occurring in dry habitats (Groups 2 to 4)																			
Stereocaulon tomentosum	1	R	R	R	R	.	1	1	+	R	1	R	R	1	1	.	.	.	14
Asahinea chrysantha	R	R	R	R	.	R	.	.	.	R	R	R	.	.	.	.	.	.	8
Salix phlebophylla	2	1	1	2	2	2	.	.	1	R	.	.	R	.	.	.	R	.	10
Pertusaria dactylina	.	R	.	R	R	R	.	.	.	.	.	.	R	.	.	.	.	.	5
Polytrichum piliferum	.	.	.	.	.	.	R	R	.	.	1	.	.	+	.	.	.	.	4
Artemisia arctica ssp. *arctica*	.	.	.	.	.	.	1	1	.	.	.	.	.	R	1	.	.	.	4
Rhytidium rugosum	.	.	.	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	4
Nephroma expallidum	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	2
Pertusaria panyrga	.	.	.	.	R	.	R	.	.	.	.	.	.	.	.	.	.	.	2
Polytrichum hyperboreum	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Taxa occurring in snowbeds to raised bog habitats (Groups 4 to 7)																			
Betula nana ssp. *exilis*	R	.	2	2	1	R	R	.	.	1	R	R	.	.	.	.	.	.	9
Aulacomnium turgidum	.	.	2	1	1	2	1	.	2	2	2	.	1	.	.	.	.	.	9
Taxa occurring in snowbeds to water tracks (Groups 4 to 6)																			
Salix planifolia ssp. *pulchra*	.	.	.	R	1	.	R	.	R	2	.	.	.	R	.	.	.	.	6
Bistorta plumosa	.	1	R	1	R	R	1	R	1	1	R	1	R	.	.	.	.	.	12
Hylocomium splendens ssp. *obtusifolium*	.	.	2	1	1	1	2	.	2	5	3	R	1	.	R	.	.	.	11
Bistorta vivipara	.	.	R	R	.	R	R	.	.	R	.	R	R	.	R	R	R	.	10
Petasites frigidus	.	.	R	1	R	R	.	.	+	.	.	.	R	.	1	R	.	.	8
Saxifraga nelsoniana	.	.	.	.	.	.	.	.	+	+	R	R	.	R	R	.	.	.	6
Tomenthypnum nitens	.	.	.	.	.	.	1	.	.	R	.	1	R	.	.	.	.	.	4
Drepanocladus uncinatus	.	.	.	.	.	.	.	.	R	.	.	.	.	3	2	.	.	.	3
Cladonia pleurota	R	R	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	4
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	.	R	.	.	+	.	.	.	2
Taxa occurring in snowbeds to uplands (Groups 4 and 5)																			
Cassiope tetragona ssp. *tetragona*	R	R	1	1	2	2	4	3	3	3	3	4	2	.	.	R	R	.	
Senecio atropurpureus ssp. *frigidus*	.	.	.	.	R	.	.	.	R	R	+	.	.	.	.	.	.	.	4
Pyrola grandiflora	.	.	.	R	.	.	R	.	1	1	+	.	.	.	.	.	.	.	5
Ledum palustre ssp. *decumbens*	.	R	2	1	R	2	.	.	1	1	2	.	.	.	.	.	.	.	8
Anastrophyllum minutum	.	R	R	R	R	R	.	.	R	R	.	.	R	R	R	.	.	.	10

(Continued)

Appendix C-2. Continued

PLOT NUMBER	43	39	29A	30A	32A	44A	41	40	57	56	55	59	26	72	73	69	70	71	FREQ
Group 4: Snowbeds, stone stripes, and frost scars (*Cassiope tetragona - Diapensia lapponica*)																			
Diapensia lapponica ssp. *obovata*	1	1	R	R	R	R	R	R	1	.	R	.	R	.	R	.	.	.	12
Pedicularis capitata	.	.	R	.	.	R	+	.	R	+	.	+	R	.	+	.	.	.	8
Huperzia selago ssp. *appressa*	.	.	.	R	.	.	R	.	R	R	R	.	R	.	R	.	.	.	7
Stellaria longipes	.	.	.	.	.	.	.	.	.	.	.	R	R	.	R	.	.	.	3
Pedicularis langsdorffii	.	.	R	1	R	R	R	.	R	R	R	.	R	.	.	.	.	.	9
Cetraria kamczatica	+	R	.	R	.	R	.	.	.	.	.	.	R	+	.	.	.	.	6
Dicranum muehlenbeckii	.	.	3	1	.	.	.	.	.	.	2	.	.	.	.	.	.	.	3
Dactylina beringica	R	.	.	.	.	.	R	+	.	.	.	.	.	.	.	.	.	.	3
Eriophorum triste	.	.	.	.	.	R	.	.	.	.	.	.	R	.	.	R	.	.	3
Loiseleuria procumbens	.	1	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.	.	3
Lophozia guttulata	.	R	.	.	.	R	.	R	.	.	.	.	.	.	.	.	.	.	3
Subgroup 4A: *Cassiope tetragona - Calamagrostis inexpansa*																			
Calamagrostis inexpansa	1	2	2	1	1	R	.	.	.	1	R	.	.	.	.	.	.	.	8
Community type *Cassiope tetragona - Calamagrostis inexpansa*																			
Dicranum groenlandicum	.	.	R	.	2	2	.	.	.	.	.	.	R	.	.	.	.	.	4
Cetraria andrejevii	.	R	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Subgroup 4B: *Cassiope tetragona - Carex microchaeta*																			
Carex microchaeta	R	R	.	.	.	.	1	2	+	1	1	R	.	.	1	.	.	.	9
Parrya nudicaulis s.l.	.	.	.	.	.	.	.	.	R	+	.	R	R	.	.	.	.	.	4
Novosieversia glacialis	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	2
Dactylina ramulosa	.	.	.	.	.	.	.	.	R	R	R	R	R	.	.	.	.	.	5
Thuidium abietinum	.	.	.	.	.	.	1	.	.	.	.	.	R	.	.	.	.	.	2
Community type *Cassiope tetragona - Carex microchaeta*																			
Nephroma arcticum	.	.	R	R	.	.	.	1	R	+	+	R	.	.	.	.	.	.	7
Pogonatum urnigerum	.	.	.	.	.	.	.	.	1	1	1	.	.	R	.	.	.	.	4
Dicranum scoparium	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	2
Ptilium cristum-castrensis	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	2
Community type *Cassiope tetragona - Dryas integrifolia*																			
Dryas integrifolia ssp. *integrifolia*	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	2
Salix reticulata ssp. *reticulata*	.	.	.	.	.	.	R	.	.	R	.	1	1	.	.	.	.	.	4
Equisetum scirpoides	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	2
Radula prolifera	.	.	.	.	.	.	R	.	.	.	.	R	R	.	.	.	.	.	3
Subgroup 4C: *Salix rotundifolia - Saxifraga rivularis*																			
Salix rotundifolia ssp. *rotundifolia*	.	.	.	.	.	.	R	.	.	1	1	.	.	3	4	.	.	.	5
Luzula confusa	.	.	.	.	.	.	.	R	.	.	R	.	.	R	R	.	.	.	4
Poa paucispicula	.	.	.	.	.	.	.	.	.	.	.	.	.	R	+	.	.	.	2
Cladonia chlorophaea	.	R	.	1	.	.	R	.	.	.	.	.	.	R	R	.	.	.	5
Solorina crocea	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	2
Subgroup 4D: *Juncus biglumus - Luzula arctica*																			
Juncus biglumis	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	1	1	2	4
Luzula arctica	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	1	R	.	4
Other species																			
Rhizocarpon geographicum	.	R	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	3
Parmelia omphalodes	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	2
Umbilicaria hyperborea	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	2
Saxifraga bronchialis ssp. *funstonii*	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	2
Arctous alpina	1	.	.	.	.	.	.	.	4	.	.	1	.	.	.	.	.	.	3
Hierochloë alpina	.	.	.	.	R	.	.	1	1	.	+	.	.	.	R	.	.	.	5
Dicranum angustum	.	.	.	.	.	.	R	.	.	.	.	1	R	.	.	.	.	.	3
Blepharostoma trichophyllum	.	.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	2
Sphagnum teres	.	.	.	.	.	.	.	.	1	R	.	.	.	.	.	.	.	.	2
Sphagnum girgensohnii	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	2
Carex bigelowii	.	.	1	1	1	.	.	.	.	.	.	R	2	R	.	.	.	.	6
Ptilidium ciliare	.	.	.	.	.	.	1	.	.	.	.	2	R	.	.	.	.	.	3
Hypnum bambergeri	.	.	.	.	.	.	.	.	.	.	R	.	R	.	.	.	.	.	2
Empetrum hermaphroditum	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2
Polytrichastrum alpinum	.	.	.	.	.	.	1	.	.	.	1	.	.	R	2	.	.	.	4
Polemonium acutiflorum	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	2
Arctagrostis latifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	R	1	.	.	.	2

(Continued)

Appendix C-2. Concluded

PLOT NUMBER	43	39	29A	30A	32A	44A	41	40	57	56	55	59	26	72	73	69	70	71	FREQ
Salix chamissonis	.	.	.	.	R	.	2	.	.	.	.	.	R	.	R	.	.	.	4
Aconitum delphinifolium ssp. *delphinifolium*		.	.	.	.	.	.	.	.	.	.	.	.	+	R	.	.	.	2
Sphagnum aongstroemii	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	2
Arnica lessingii	.	.	R	R	R	.	R	.	.	.	.	.	R	R	1	.	.	.	7
TOTAL SPECIES FREQUENCY	36	47	44	50	47	45	50	42	51	60	55	55	67	41	35	7	9	2	
PLOT NUMBER	43	39	29A	30A	32A	44A	41	40	57	56	55	59	26	72	73	69	70	71	

SINGLE OCCURRENCES (PLOT NUMBER: SPECIES):Plot 39: *Cladonia deformis, Cladonia cornuta*; Plot 29A: *Stereocaulon paschale*; Plot 30A: *Peltigera scabrosa*; Plot 32A: *Cetraria nigricans, Cetraria laevigata, Dicranella varia*; Plot 44A: *Polytrichum commune, Sphagnum warnstorfii*; Plot 41: *Peltigera leucophlebia*; Plot 40: *Gentiana glauca, Lecidea flavocaerulescens*; Plot 57: *Sphagnum lenense, Macrodiplophyllum plicatum, Pseudolepicola fryei, Cladonia stellaris*; Plot 56: *Sphagnum rubellum, Gymnomitriom concinnatum*; Plot 59: *Dryas octopetala* ssp. *octopetala, Kobresia myosuroides, Carex scirpoidea, Acomastylis rossii, Astragalus umbellatus, Equisetum variegatum ssp. variegatum, Papaver macounii, Rhododendron lapponicum, Salix arctica, Saussurea angustifolia, Solorina saccata*; Plot 26: *Tofieldia pusilla, Scapania simsonii, Orthilia secunda* ssp. *obtusata, Carex saxatilis* ssp. *laxa, Carex vaginata, Aneura pinguis, Salix fuscescens, Pedicularis albolabiata, Tortula ruralis*; Plot 72: *Saxifraga rivularis, Saxifraga nivalis, Silene acaulis, Polytrichum sexangulare, Carex podocarpa, Lecidea demissa, Cladonia ecmocyna*; Plot 73: *Anemone parviflora, Cetraria delisei, Diplophyllum albicans, Diplophyllum opacifolia*; Plot 71: *Eriophorum vaginatum*

Appendix C-3. Sorted table of moist communities.

PLOT NUMBER	61	3	50	62	4A	27	45	31	6	12	8	1	7	35A	24	67	5	15	10	13	17	48	46	FREQ
Taxa occurring in blockfields to moist habitats (Groups 1 to 5)																								
Polytrichum strictum	1	R	1	2	R	1	R	1	1	1	2	R	.	1	2	1	+	2	1	2	.	1	1	21
Cetraria cucullata	+	R	1	R	.	R	1	R	1	R	1	R	R	R	2	1	R	R	R	R	R	1	R	22
Cetraria islandica	R	R	R	R	.	R	R	R	R	R	R	R	R	.	1	R	R	R	.	.	R	R	.	18
Cladonia amaurocraea	R	R	1	R	.	R	1	R	.	R	R	R	R	.	1	2	R	R	R	.	R	.	R	18
Dactylina arctica	+	R	R	R	.	R	R	R	R	R	1	R	R	.	1	1	R	R	.	R	+	R	.	19
Cladonia gracilis	R	1	.	R	.	R	R	R	1	R	1	.	R	R	1	1	R	.	R	.	.	+	.	16
Cladonia rangiferina	R	R	1	R	.	1	1	R	R	R	1	R	R	R	2	2	R	R	R	.	R	R	.	20
Vaccinium uliginosum	.	1	R	.	1	1	1	.	1	.	1	2	1	.	R	.	1	.	.	R	1	.	.	13
Thamnolia spp.	.	R	R	.	.	R	R	.	R	.	R	R	.	.	.	R	.	R	.	.	.	.	.	9
Cetraria nivalis	.	R	R	.	.	R	.	.	.	.	2	.	.	.	R	.	.	.	.	.	.	R	.	6
Cladonia arbuscula	R	.	R	.	.	1	.	R	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	6
Poa arctica	.	.	R	.	.	.	.	R	.	.	R	.	.	R	.	.	.	.	.	.	.	+	.	5
Taxa occurring in dry to moist habitats (Groups 2 to 5)																								
Vaccinium vitis-idaea ssp. *minus*	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	2	2	.	1	2	1	2	1	22
Cetraria richardsonii	.	R	.	.	.	.	.	R	R	R	R	.	.	.	.	.	.	R	.	.	.	.	.	6
Peltigera aphthosa	+	.	+	.	R	.	R	R	R	R	R	.	.	R	.	.	R	.	.	R	.	+	.	12
Dicranum elongatum	.	.	2	.	.	.	2	R	.	.	2	1	1	.	3	R	.	.	1	+	.	1	.	11
Cladonia mitis	.	1	R	.	.	.	.	.	.	R	R	R	R	.	1	2	.	.	.	.	R	.	.	9
Taxa occurring in snowbeds to raised bog habitats (Groups 4 to 7)																								
Betula nana ssp. *exilis*	1	1	1	2	1	.	2	1	3	3	2	1	2	1	2	2	3	3	3	2	2	4	4	22
Aulacomnium turgidum	2	2	2	2	1	2	3	2	2	2	2	1	2	1	2	2	2	2	1	2	2	2	2	23
Taxa occurring in snowbeds to water tracks (Groups 4 to 6)																								
Salix planifolia ssp. *pulchra*	2	2	2	2	2	2	.	2	1	2	1	2	3	3	.	.	2	.	2	2	.	1	1	18
Bistorta plumosa	+	R	R	R	.	R	R	R	1	1	1	.	R	R	.	.	R	.	1	1	.	+	R	17
Hylocomium splendens ssp. *obtusifolium*	2	2	2	2	2	3	2	2	3	2	R	2	3	2	R	2	3	R	2	2	R	4	3	23
Bistorta vivipara	.	.	.	.	.	R	.	R	.	R	.	.	.	R	.	.	R	.	.	.	.	.	.	5
Petasites frigidus	+	.	R	R	1	1	1	2	1	R	1	R	1	2	.	.	1	.	1	R	.	1	R	18
Saxifraga nelsoniana	R	.	R	R	R	.	.	.	R	R	.	.	R	R	.	.	R	.	.	.	.	R	.	10
Tomenthypnum nitens	1	R	R	1	1	R	R	.	R	R	.	R	1	R	.	.	R	.	R	.	.	.	R	15
Drepanocladus uncinatus	.	.	.	R	1	.	R	.	.	R	.	.	1	1	.	.	1	.	R	R	.	.	R	10
Cladonia pleurota	R	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	R	.	4
Cladonia deformis	.	.	R	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	2
Drepanocladus revolvens	.	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Taxa occurring in snowbeds to uplands (Groups 4 and 5)																								
Cassiope tetragona ssp. *tetragona*	1	R	.	1	.	1	2	1	R	1	R	1	R	R	.	1	1	.	.	.	R	.	.	15
Senecio atropurpureus ssp. *frigidus*	R	.	R	.	.	R	R	R	R	.	.	R	R	.	.	.	.	.	.	.	.	.	.	8
Pyrola grandiflora	+	.	R	+	.	1	1	+	.	.	.	.	R	R	.	.	+	.	.	.	R	.	.	10
Ledum palustre ssp. *decumbens*	1	1	1	1	1	R	1	1	1	1	2	1	1	R	2	2	1	.	1	1	1	R	R	22
Anastrophyllum minutum	1	R	1	.	R	R	R	R	R	.	.	.	.	R	R	.	.	R	.	R	R	1	R	15

(Continued)

Appendix C-3. Continued

PLOT NUMBER	61	3	50	62	4A	27	45	31	6	12	8	1	7	35A	24	67	5	15	10	13	17	48	46	FREQ
Taxa occurring in moist to raised bog habitats (Groups 5 to 7)																								
Sphagnum rubellum	1	1	1	2	1	1	2	1	1	2	2	2	1	2	1	1	2	2	2	1	2	R	2	23
Rubus chamaemorus	1	R	1	1	R	.	.	.	1	1	R	R	2	1	2	2	1	2	1	1	2	R	2	20
Dicranum angustum	1	1	1	1	R	.	2	R	1	1	1	1	.	1	1	.	2	1	1	+	1	1	1	20
Aulacomnium palustre	.	R	1	1	1	.	1	1	2	2	2	1	2	2	.	.	2	.	2	2	.	1	2	17
Blepharostoma trichophyllum	R	R	.	1	R	.	R	R	R	R	.	.	.	R	.	.	R	R	.	R	R	R	R	15
Tritomaria quinquedentata	.	.	.	R	.	R	R	R	.	R	.	R	.	R	R	.	R	R	.	.	.	.	R	11
Pohlia nutans	R	.	.	.	.	R	R	R	R	R	.	R	.	R	R	.	R	R	R	.	R	.	.	13
Sphagnum teres	1	.	.	2	1	.	.	.	2	3	2	.	2	.	.	.	3	3	2	.	.	R	2	12
Pedicularis lapponica	.	.	.	.	.	.	.	.	R	R	.	R	R	.	R	.	+	1	R	R	R	.	.	10
Sphagnum girgensohnii	.	R	.	.	.	R	.	.	R	.	R	.	.	.	R	.	1	1	1	R	.	.	.	9
Sphagnum angustifolium	.	.	.	1	.	.	.	1	.	R	.	.	.	2	R	.	1	.	.	.	1	.	.	7
Pedicularis labradorica	.	.	.	R	.	.	.	.	.	.	.	.	R	.	.	.	.	R	.	.	.	.	.	3
Rhizomnium andrewsianum	.	R	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	2
Cetraria fastigiata	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	2
Group 5: Upland tundra (*Eriophorum vaginatum - Sphagnum rubellum*)																								
Eriophorum vaginatum	3	3	3	3	3	.	1	R	R	2	1	1	2	.	2	1	.	R	.	1	2	.	R	18
Carex bigelowii	2	2	2	1	2	3	3	3	3	3	2	2	2	2	R	.	2	R	2	2	.	2	2	21
Ptilidium ciliare	R	1	.	2	.	R	R	R	.	R	.	1	1	R	.	1	1	.	.	.	.	.	R	13
Hypnum bambergeri	R	R	R	.	.	1	.	R	.	.	.	R	.	R	.	.	R	.	R	.	.	.	.	9
Peltigera scabrosa	+	R	R	R	.	R	.	R	.	.	R	.	R	R	.	.	.	.	R	R	R	R	.	13
Cladonia carneola	.	R	R	.	.	.	.	.	.	R	R	R	.	.	R	.	.	.	R	.	.	.	.	7
Cladonia cenotea	.	R	R	.	.	.	.	.	R	.	.	R	.	.	.	R	.	.	.	.	.	.	.	5
Cladonia fimbriata	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	R	.	.	.	.	2
Peltigera polydactyla	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	2
Subgroup 5A: *Eriophorum vaginatum - Sphagnum rubellum*																								
Empetrum hermaphroditum	1	1	R	.	R	.	.	.	R	1	1	1	.	.	.	.	R	.	.	.	.	.	.	9
Drepanocladus badius	.	R	.	R	2	R	R	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	6
Lophozia binsteadii	R	.	.	.	.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	3
Community type *Eriophorum vaginatum - Sphagnum rubellum*																								
Meesia uliginosa	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Taxa occurring in shrub communities to moist bogs (Groups 5B to 7)																								
Polytrichastrum alpinum	.	.	.	.	.	.	.	.	.	.	.	.	1	.	R	.	.	.	R	.	.	.	.	3
Polytrichum commune	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	2	.	.	2
Scapania paludicola	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	1	.	.	R	.	.	.	3
Subgroup 5C: *Betula nana - Sphagnum rubellum*																								
Cetraria sepincola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	R	.	.	.	2
Parmelia septentrionalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	2
Other species																								
Alectoria ochroleuca	R	.	.	.	.	.	R	.	.	.	R	.	.	.	.	R	.	.	.	.	.	.	.	4
Sphaerophorus globosus	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	.	R	.	.	.	.	2
Cornicularia divergens	.	.	.	.	.	.	.	.	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	2
Cladonia uncialis	.	.	R	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3

(Continued)

Appendix C-3. Concluded.

PLOT NUMBER	61	3	50	62	4A	27	45	31	6	12	8	1	7	35A	24	67	5	15	10	13	17	48	46	FREQ
Dicranum acutifolium	.	.	.	.	R	.	.	R	.	.	.	.	.	.	R	.	.	.	.	.	R	.	.	4
Alectoria nigricans	.	.	R	.	.	.	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	3
Pertusaria dactylina	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Arctous alpina	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	2
Pedicularis langsdorffii	.	R	.	.	.	R	.	R	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	4
Dicranum groenlandicum	1	2	.	.	.	.	.	.	1	1	.	.	.	.	.	R	.	.	.	.	.	.	.	5
Dactylina ramulosa	.	.	.	.	.	R	.	R	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	3
Salix reticulata ssp. *reticulata*	R	R	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Cladonia chlorophaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	2
Eriophorum angustifolium ssp. *subarcticum*	.	.	.	.	1	.	.	.	.	.	R	.	.	R	.	.	.	R	R	.	R	.	R	7
Campylium stellatum	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	R	.	.	.	.	.	.	2
Calliergon stramineum	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	R	.	.	R	.	.	4
Arctagrostis latifolia	.	.	.	.	.	.	.	.	.	R	R	.	.	R	.	.	.	.	R	.	.	.	.	4
Salix fuscescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	1	.	.	.	.	.	2
Andromeda polifolia	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	R	.	.	R	.	.	4
Carex rotundata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	2
Pedicularis albolabiata	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	.	2
Sphagnum lenense	.	1	.	.	.	.	.	1	.	.	.	2	.	.	2	.	.	R	.	R	4	.	.	7
Sphagnum aongstroemii	.	.	.	.	R	.	.	.	.	.	.	.	.	.	R	.	R	R	R	.	R	.	.	6
Arnica lessingii	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	2
TOTAL SPECIES FREQUENCY	43	48	44	40	33	41	37	48	45	44	47	43	38	36	43	28	47	39	39	33	33	33	29	
PLOT NUMBER	61	3	50	62	4A	27	45	31	6	12	8	1	7	35A	24	67	5	15	10	13	17	48	46	

SINGLE OCCURRENCES (PLOT NUMBER: SPECIES): Plot 61: *Valeriana capitata*; Plot 03: *Pleurozium schreberi*; Plot 62: *Saxifraga cernua*; Plot 04A: *Peltigera malacea*; Plot 27: *Anemone parviflora, Pedicularis capitata, Dicranum muehlenbeckii*; Plot 45: *Peltigera horizontalis*; Plot 31: *Nephroma arcticum, Cetraria inermis, Cirriphyllum cirrosum*; Plot 06: *Cladonia coccifera, Cetraria kamczatica*; Plot 08: *Rhacomitrium lanuginosum, Salix phlebophylla, Lobaria linita*; Plot 01: *Cladonia sulphurina*; Plot 07: *Luzula wahlenbergii, Sphagnum nemoreum*; Plot 35A: *Paludella squarrosa*; Plot 24: *Carex rariflora, Mylia anomala*; Plot 67: *Cladonia ecmocyna*; Plot 05: *Sphagnum imbricatum*; Plot 15: *Eriophorum scheuchzeri* ssp. *scheuchzeri, Carex aquatilis s.l., Sphagnum compactum, Sphagnum magellanicum*; Plot 10: *Polemonium acutiflorum, Festuca altaica, Cetraria pinastri*; Plot 48: *Lophozia guttulata, Cladonia subulata, Cladonia macrophylla*

(Continued)

Appendix C-4. Sorted table of wet communities.

PLOT NUMBER	36A	02	49	34	11	18	47	20	14	25A	19	22B	21A	22A	25B	16	23	37	65	66	FREQ
Taxa occurring in snowbeds to raised bog habitats (Groups 4 to 7)																					
Betula nana ssp. *exilis*	1	R	.	.	2	1	.	1	1	2	1	1	.	.	R	.	.	.	.	.	10
Aulacomnium turgidum	.	.	.	.	R	R	.	1	2	2	2	1	.	.	R	.	.	.	.	.	8
Taxa occurring in snowbeds to water tracks (Groups 4 to 6)																					
Salix planifolia ssp. *pulchra*	3	3	4	3	2	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	8
Bistorta plumosa	R	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Hylocomium splendens ssp. *obtusifolium*	2	1	2	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	5
Bistorta vivipara	R	.	R	.	.	+	R	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Petasites frigidus	1	.	R	2	1	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Saxifraga nelsoniana	1	R	R	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Tomenthypnum nitens	R	R	1	R	R	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Drepanocladus uncinatus	R	2	3	2	.	R	3	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Taxa occurring in moist to raised bog habitats (Groups 5 to 7)																					
Sphagnum rubellum	2	1	1	1	1	1	1	2	2	2	2	1	.	R	R	.	.	.	.	.	14
Rubus chamaemorus	1	R	.	R	1	R	.	R	2	.	R	.	.	.	.	.	.	.	.	.	8
Dicranum angustum	.	.	.	R	.	1	.	.	R	R	R	.	.	.	.	.	.	.	.	.	5
Aulacomnium palustre	2	1	2	1	R	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	7
Blepharostoma trichophyllum ssp. *brevirete*	.	.	.	.	R	.	.	.	R	R	.	.	.	.	R	.	.	.	.	.	4
Tritomaria quinquedentata	.	.	.	.	R	R	R	.	R	R	R	.	.	.	R	.	.	.	.	.	7
Pohlia nutans	R	.	.	.	R	R	.	R	.	.	R	.	.	.	.	.	.	.	.	.	5
Sphagnum teres	.	1	.	.	R	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Pedicularis lapponica	.	.	.	.	.	.	.	+	1	1	R	R	.	.	.	.	.	.	.	.	5
Sphagnum girgensohnii	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Sphagnum angustifolium	2	1	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	.	4
Saxifraga cernua	.	R	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Taxa occurring in shrub communities to moist bogs (Groups 5B to 7)																					
Polytrichastrum alpinum	.	.	.	.	.	1	1	.	2	.	.	.	.	.	.	.	.	.	.	.	3
Polytrichum commune	.	.	.	.	1	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	3
Scapania paludicola	.	.	.	.	R	.	.	R	.	R	.	.	R	.	R	.	.	.	.	.	5
Aneura pinguis	.	.	.	.	.	.	R	.	.	.	.	.	R	.	.	.	R	.	.	.	3
Mylia anomala	.	.	.	.	.	.	.	.	.	.	.	R	.	R	.	.	.	.	.	.	2
Sphagnum compactum	.	.	.	.	.	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	2
Group 6: Water tracks and streamsides (*Eriophorum angustifolium - Valeriana capitata*)																					
Eriophorum angustifolium ssp. *subarcticum*	2	3	2	4	3	.	R	.	.	R	R	.	R	R	.	3	1	.	.	.	12
Valeriana capitata	R	R	1	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Paludella squarrosa	R	R	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	R	5
Bryum pseudotriquetrum	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Campylium stellatum	.	2	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Calliergon stramineum	.	.	.	2	R	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	4
Subgroup 6A: *Salix planifolia - Eriophorum angustifolium*																					
Polemonium acutiflorum	1	R	R	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Arctagrostis latifolia	R	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3

(Continued)

Appendix C-4. Continued

PLOT NUMBER	36A	02	49	34	11	18	47	20	14	25A	19	22B	21A	22A	25B	16	23	37	65	66	FREQ
Subgroup 6B: *Carex aquatilis* - *Salix chamissonis*																					
Salix chamissonis	.	.	1	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Aconitum delphinifolium ssp. *delphinifolium*	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Dodecatheon frigidum	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Potentilla palustris	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	R	.	2
Group 7: Bogs (*Salix fuscescens* - *Carex rariflora*)																					
Salix fuscescens	.	1	.	.	.	2	1	2	1	2	2	1	R	1	R	.	.	.	.	.	11
Carex rariflora	.	.	.	.	.	1	+	1	1	2	1	1	2	2	2	.	.	.	.	.	10
Eriophorum scheuchzeri ssp. *scheuchzeri*	.	.	.	.	.	1	.	.	.	2	2	1	2	1	1	R	1	.	.	.	9
Andromeda polifolia	.	.	.	.	.	R	.	.	R	1	.	1	R	R	R	.	.	.	.	.	7
Carex rotundata	.	.	.	.	.	R	.	2	.	1	1	.	2	1	1	.	2	.	.	.	8
Sphagnum imbricatum	.	.	.	.	.	.	.	.	2	2	.	R	1	1	1	.	.	.	.	.	6
Pedicularis albolabiata	.	.	.	.	.	R	R	.	.	R	.	R	R	1	1	.	R	.	.	.	8
Community type *Salix fuscescens* - *Sphagnum lenense*																					
Sphagnum lenense	.	.	.	.	.	R	.	3	2	1	4	2	.	.	.	.	.	.	.	.	6
Sphagnum aongstroemii	.	.	.	.	.	.	.	1	R	R	1	.	.	.	.	.	.	.	.	.	4
Sphagnum warnstorfii	.	.	1	.	.	R	1	R	R	.	R	.	.	.	.	.	.	.	.	.	6
Sphagnum fimbriatum	.	.	.	.	.	R	1	.	1	1	.	R	.	.	R	.	.	.	.	.	6
Eriophorum russeolum	.	.	R	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2
Community type *Carex rotundata* - *Sphagnum lindbergii*																					
Sphagnum lindbergii	.	.	.	.	.	.	.	.	R	.	.	.	4	2	2	.	.	1	2	.	6
Group 8: Shallow water (*Carex aquatilis* - *Eriophorum angustifolium*)																					
Carex aquatilis s.l.	.	.	2	.	.	3	3	.	2	.	.	.	.	.	.	4	3	.	.	.	6
Sphagnum subsecundem	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	.	.	.	2
Group 9: Deep water (*Sparganium hyperboreum* - *Hippuris vulgaris*)																					
Sparganium hyperboreum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	4	3
Hippuris vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	R	.	2
Sphagnum squarrosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	R	3
Other species																					
Polytrichum strictum	R	.	.	.	1	.	.	2	.	.	.	.	R	.	.	.	.	.	.	.	4
Cetraria cucullata	.	.	.	.	.	.	.	.	R	R	R	.	.	.	.	.	.	.	.	.	3
Vaccinium uliginosum	.	.	.	.	.	R	.	.	R	.	.	R	.	.	.	.	.	.	.	.	3
Poa arctica	R	R	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Vaccinium vitis-idaea ssp. *minus*	.	.	.	.	.	.	.	.	R	R	R	.	.	.	.	.	.	.	.	.	3
Anastrophyllum minutum	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	.	2
Huperzia selago ssp. *appressa*	.	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.	.	2
Salix reticulata ssp. *reticulata*	R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Carex bigelowii	1	.	.	.	R	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	3
TOTAL SPECIES FREQUENCY	27	27	20	19	20	35	39	24	39	23	21	15	13	11	18	4	7	5	5	4	
PLOT NUMBER	36A	02	49	34	11	18	47	20	14	25A	19	22B	21A	22A	25B	16	23	37	65	66	

(Continued)

Appendix C-4. Concluded

SINGLE OCCURRENCES (PLOT NUMBER: SPECIES):Plot 36A: *Plagiomnium medium*; Plot 02: *Stellaria longipes, Cardamine pratensis* ssp. *angustifolia, Equisetum arvense, Brachythecium groenlandicum, Brachythecium turgidum, Peltigera aphthosa*; Plot 34: *Polytrichum longisetum, Pohlia andrewsii*; Plot 18: *Saxifraga foliolosa, Pedicularis labradorica, Campanula lasiocarpa*; Plot 47: *Artemisia arctica* ssp. *arctica, Anemone parviflora, Calamagrostis inexpansa, Carex obtusata, Lophozia quadriloba*; Plot 20: *Sphagnum orientale, Cladonia rangiferina*; Plot 14: *Cassiope tetragona* ssp. *tetragona, Pedicularis langsdorffii, Sphagnum magellanicum, Rhizomnium andrewsianum, Cetraria islandica, Cetraria fastigiata, Dactylina arctica, Thamnolia* spp.*, Cladonia mitis, Pseudolepicola fryei*; Plot 25A: *Ptilidium ciliare*; Plot 25B: *Drepanocladus badius, Drepanocladus revolvens, Splachnum sphaericum*; Plot 66: *Polytrichum swartzii*

(Continued)

Appendix D. Soil water chemistry data for 1988.

Date	Length	Site	Volume	pH	EC	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Mn	Fe	F^{-}	Cl^{-}	HPO_4^{-2}	NO_3^{-}	SO_4^{-2}
8/25/88	Long	C-4	20	•	•	0.21	0.183	3.221	0.638	0.021	3.314	0	5.613	0	0.693	1.517
8/25/88	Long	C-6	40	•	•	0.76	0.614	1.759	0.2	0.218	0.601	0	0.323	0	0	1.374
8/25/88	Long	C-7	100	6.1	320	0.429	0.333	0.983	0.139	0.052	0.417	0.452	0	1.916	0	0
8/25/88	Long	C-8	60	6.4	260	1.147	0.479	1.177	0.216	0.551	1.863	0.51	0	0.924	0	0
8/25/88	Long	C-9	180	5.6	330	1.226	0.56	0.903	0.162	0.892	5.482	0	-0.933	0	0	0.45
8/25/88	Long	C-10	100	•	•	0.982	0.759	0.712	0.134	0.265	•	0	-0.835	0	0	0.299
8/25/88	Long	C-11	60	•	•	0.984	0.324	1.163	0.238	0.185	4.659	0	-0.03	0	0	0.509
8/25/88	Long	C-12	50	•	•	2.498	0.756	2.029	0.169	0.279	8.606	0	6.003	0	0	0.54
8/25/88	Long	C-14	30	•	•	0.436	0.27	2.893	0.282	0.063	2.236	-0.458	3.332	0	0	0.521
8/25/88	Short	C-3	40	•	•	•	•	•	•	•	•	•	•	•	•	0.718
8/25/88	Short	C-4	85	•	•	0.434	0.198	1.456	0.384	-0.002	0.816	0	9.087	0	0	0.42
8/25/88	Short	C-6	50	•	•	•	•	•	•	•	•	•	•	•	•	0.85
8/25/88	Short	C-7	50	•	•	0.325	0.205	0.915	0.152	0.035	1.295	0	3.443	0	0	0.421
8/25/88	Short	C-8	75	•	•	0.226	0.182	1.819	0.212	0.072	0.05	0	1.009	0	0	0.525
8/25/88	Short	C-9	60	6.4	205	0.158	0.158	1.394	0.173	0.047	0.395	0	-0.298	0	0	0.531
8/25/88	Short	C-10	180	•	•	0.343	0.304	1.177	0.115	0.472	0.09	0	-0.345	0	0	0.128
8/25/88	Short	C-11	100	•	•	0.218	0.224	1.801	0.193	0.021	0.728	0	0.995	0	0	0.217
8/25/88	Short	C-12	110	5.575	320	3.307	0.808	0.689	0.161	0.912	8.943	0	-0.352	0	0	0.874
8/25/88	Short	C-14	135	5.3	270	0.623	0.29	1.133	0.373	0.029	2.144	0	-0.441	0	0	0.406
8/28/88	Long	C-3	215	•	•	•	•	•	•	•	•	•	•	•	•	0.241
8/28/88	Long	C-4	135	•	•	•	•	•	•	•	•	•	•	•	•	0.344
8/28/88	Long	C-6	215	6.3	315	1.695	0.996	1.188	0.439	0.569	2.856	0.302	0.459	0	0	0
8/28/88	Long	C-7	135	5.875	340	0.886	0.433	0.667	0.122	0.071	0.239	0	-0.319	0	0	0.257
8/28/88	Long	C-8	150	5.9	440	2.247	0.701	0.781	0.128	1.148	3.11	0.605	-0.352	0	0	0.548
8/28/88	Long	C-9	260	5.95	400	1.467	0.734	0.625	0.125	1.446	6.273	0.408	-0.545	0	0	0.213
8/28/88	Long	C-10	75	5.925	720	1.642	0.954	0.606	0.118	0.323	•	0.884	0	0	0	0.532
8/28/88	Long	C-11	100	5.5	265	1.61	0.368	0.585	0.134	0.322	2.777	0.171	-0.713	0	0	0
8/28/88	Long	C-12	145	5.75	570	3.399	1.063	0.71	0.118	0.393	6.479	0.596	2.821	0	0	0.214
8/28/88	Long	C-14	120	4.925	350	1.224	0.468	1.266	0.295	0.052	4.277	1.163	0	0	0	0
8/28/88	Short	C-3	100	•	•	•	•	•	•	•	•	•	•	•	•	0.31
8/28/88	Short	C-4	125	•	•	0.307	0.205	0.886	0.118	-0.007	0.619	0	0.44	0	0	0.305
8/28/88	Short	C-6	125	•	•	•	•	•	•	•	•	•	•	•	•	0.191
8/28/88	Short	C-7	160	6.35	250	0.928	0.305	0.79	0.132	0.017	0.791	-0.086	-0.338	0.797	0	0.512
8/28/88	Short	C-8	100	6	180	1.043	0.353	0.669	0.208	0.158	0.098	0	-0.423	0	0	0.469
8/28/88	Short	C-9	30	6.1	150	1.017	0.346	0.751	0.214	0.186	0.024	0.508	0	0.694	0	1.376
8/28/88	Short	C-10	30	6.075	320	0.97	0.322	0.592	0.383	0.179	0.442	0	0.418	0	0	0.749

(Continued)

Appendix D. Concluded.

Date	Length	Site	Volume	pH	EC	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Mn	Fe	F^{-}	Cl^{-}	HPO_4^{-2}	NO_3^{-}	SO_4^{-2}
8/28/88	Short	C-11	25	5.3	400	1.051	0.381	0.737	0.468	0.077	0.445	0	0.818	0	0	0.906
8/28/88	Short	C-12	60	5.5	420	3.235	0.771	0.803	0.177	0.953	9.944	0.206	-0.385	0	0	0.504
8/28/88	Short	C-14	40	5.6	260	0.795	0.31	1.042	0.424	0.03	3.23	0	0.529	0	0	0.46
9/1/88	Long	C-3	50	•	•	•	•	•	•	•	•	•	•	•	•	0.406
9/1/88	Long	C-4	30	•	•	•	•	•	•	•	•	•	•	•	•	0.741
9/1/88	Long	C-6	110	•	•	1.867	1.145	1.336	0.637	0.777	3.51	0.047	-0.221	0	0	1.333
9/1/88	Long	C-7	•	•	•	1.407	0.432	•	0.32	0.09	0.631	-0.117	4.554	0	0.3	1.082
9/1/88	Long	C-8	20	•	•	2.257	0.891	•	0.236	1.135	3.91	0.362	4.509	0	0	1.019
9/1/88	Long	C-9	250	•	•	0.902	0.743	0.31	0.187	1.279	6.571	0.234	4.325	0	0.224	0.322
9/1/88	Long	C-10	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9/1/88	Long	C-11	•	•	•	0.88	0.332	1.287	0.205	0.371	3.311	0	0.014	0	0	•
9/1/88	Long	C-12	•	•	•	3.412	0.995	•	0.208	0.321	5.801	0.194	1.571	0.258	0	•
9/1/88	Long	C-14	•	•	•	0.658	0.405	2.448	0.331	0.077	2.867	0.414	2.038	0	0	•
9/1/88	Short	C-3	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9/1/88	Short	C-4	•	•	•	0.84	0.206	•	0.203	0.006	1.229	-0.039	4.647	0	0.375	•
9/1/88	Short	C-6	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9/1/88	Short	C-7	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9/1/88	Short	C-8	•	6.175	330	1.276	0.412	0.847	1.433	0.209	0.254	0	9.102	0	0	•
9/1/88	Short	C-9	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9/1/88	Short	C-10	•	•	•	•	•	•	•	•	•	•	•	•	•	•
9/1/88	Short	C-11	•	•	•	0.858	0.314	•	0.445	0.092	0.53	0.128	6.887	0	0.269	•
9/1/88	Short	C-12	•	•	•	2.963	0.65	•	•	0.735	7.138	-0.319	7.604	0	0.351	•
9/1/88	Short	C-14	•	5.625	270	0.933	0.32	0.533	0.224	0.034	4.26	0	-0.214	0	0	•

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. Biological Report 89(7)

2.

3. Recipient's Accession No.

4. Title and Subtitle
Wetland Soils and Vegetation, Arctic Foothills, Alaska

5. Report Date
June 1989

6.

7. Author(s)
M.D. Walker, D.A. Walker, and K.R. Everett

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Walker Geobotanical Surveys
956 Clover Circle
Lafayette, CO 80026

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) 14-16-0009-85-001
(G)

12. Sponsoring Organization Name and Address
National Ecology Research Center
U.S. Fish and Wildlife Service
2627 Redwing Rd
Fort Collins, CO 80526-2899

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)
Analyses of relationships between hydric soils and wetland plant species were made at a 22 km^2 site in the northern foothills of the Brooks Range, Alaska, as part of a cooperative effort between the FWS and SCS to develop methods for field identification of wetlands and hydric soils. The site is considered to be representative of broad regions of acidic tussock tundra in the foothills. Seven soil types (subgroups) were identified at the site: Pergelic Cryofibrists, Hemic Pergelic Sphagnofibrists, Pergelic Cryohemists, Histic Pergelic Cryaquepts, Pergelic Cryaquepts, Pergelic Cryorthents, and Pergelic Cryochrepts. All except the last two are considered hydric. Weighted and index averages were calculated for each of 84 samples by weighting each species according to its wetland indicator status in a published list of vascular wetland plants of the U.S. Analysis of variance among soil types using averages based on vascular species alone or in combination with cryptogamic species (mosses, liverworts, and lichens) led to a highly significant stastical distinction between hydric and non-hydric soils. Cryptogamic species, which have not been reviewed for wetland status, did not separate the soil types properly. Bryophytes produced indices that were too low, i.e., toward the wet end of the scale, and lichens produced indices that were too high. Thus, indices based on vascular species alone, which are easiest to identify in the field, appear adequate for separating hydric and non-hydric soils.

17. Document Analysis a. Descriptors
Wetland ecosystems
Wetland soils
Wetland vegetation
Wetland ecology

b. Identifiers/Open-Ended Terms
Alaska wetlands
Tundra wetlands

c. COSATI Field/Group

18. Availability Statement
Release unlimited

19. Security Class (This Report)
Unclassified

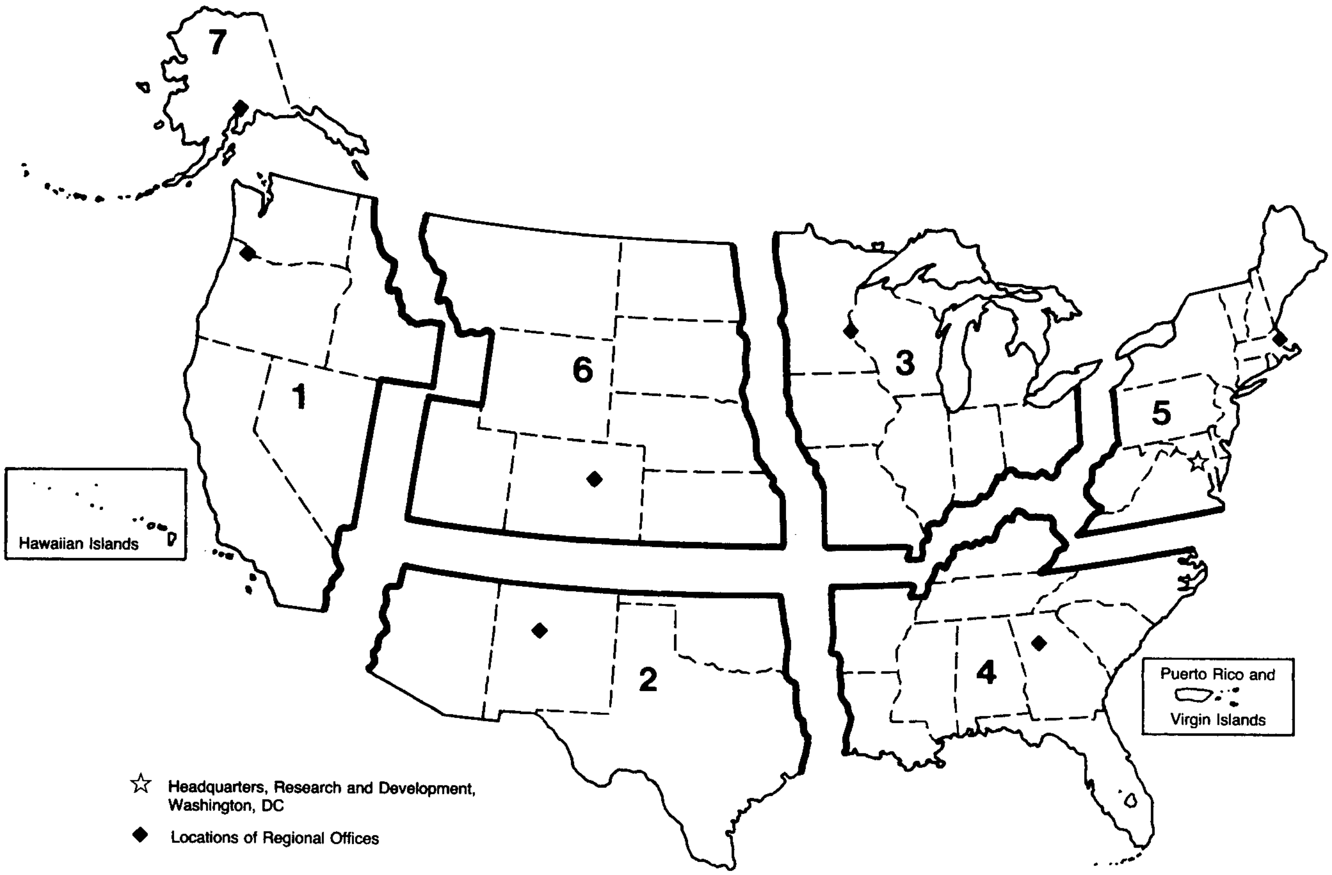
20. Security Class (This Page)
Unclassified

21. No. of Pages
89

22. Price

(See ANSI–Z39.18) *See Instructions on Reverse*

OPTIONAL FORM 272 (4–77)
(Formerly NTIS–35)
Department of Commerce



REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
WASHINGTON, D.C. 20240

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTERIOR
INT-423

U.S.MAIL